The financial accelerator in the housing market via collateral effects and the role of monetary policy in an estimated New Keynesian DSGE model

A Norwegian case study

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Preface

This master thesis marks the end of my master degree in Economics at the University of Oslo.

Als meus pares

I would like to express my gratitude towards my supervisor Tommy Sveen for coming up with the idea of writing about the financial accelerator within the housing market, teaching me the programming tool Dynare and for answering my countless e-mails. I would also like to thank Norges Bank for providing me with data. Ragnar Nymoen, Asbjørn Rødseth, Steinar Holden and Nina Midthjell from the university were also of great assistance in the process.

I am eternally grateful to my good friend Kenneth for reading through my thesis and giving me invaluable pointers; let`s call it even mate. On that note, I would also like to thank Ellen for proofreading parts of my thesis, and for encouraging my caffeine addiction with coffee breaks these 5 years at the Uni. Lastly, I would like to thank my family for the great support I have received.

All remaining errors and weaknesses are my own responsibility.

Dior Kurta, May 2011

Abstract

This thesis aims to show the financial accelerator mechanism in the housing sector using Norwegian data for the period 1995-2010. Housing is the most important investment decision an agent makes during his/her lifetime. Most Norwegian households own their own home and have during the last 15 years experienced an astonishing 400% nominal rate of return on their investment. Mortgage Equity Withdrawal (MEW) is a relatively new phenomenon that allows households to withdraw money from increasing housing markets to finance increased spending today. Seeing that more than 50% of household assets are tied to housing, adverse changes in the housing market will consequently have severe repercussions for the rest of the economy through the MEW channel. Real and monetary shocks hitting the economy affect the net worth of households and therefore amplify and propagate the initial shock, making it more persistent and longer lasting. This is known as the financial accelerator in the literature.

This thesis is divided into two parts. First, I estimate a closed economy New Keynesian Dynamic Stochastic General Equilibrium (DSGE) model for Norwegian data using a Bayesian framework. I then look into the importance of collateral effects in amplifying monetary shocks to the economy and hypothesise what would happen if the wage share of the credit constrained consumers increase. I find that during the last decade, there has been a liberalisation of credit markets and it has become increasingly easier to obtain credit, leading to the consumption boom we are experiencing. Having realised that the sheer size of household debt has grown substantially more than income the last couple of decades, it is a concerning development and one that should not be taken easily. Second, I look into the monetary policy rule and theorise whether central banks should aim to stabilise asset prices as well as keeping inflation and output stable. I find that incorporating asset prices in the policy specification of the central bank leads to a statistically insignificant coefficient. This is not in contrast to the literature on this field of research, although some studies have conversely found that it will be welfare enhancing for the central bank to stabilise asset prices as well.

Content

1 Introduction

"Ever tried. Ever failed. No matter. Try again. Fail again. Fail better."

Samuel Beckett

Housing is the most important single asset in most households' portfolios. The biggest investment decision households make is whether or not to enter the housing market. Adverse changes in the housing market will therefore have severe repercussions for the rest of the economy. The main goal of this paper is to estimate and analyse a DSGE model incorporating financial frictions in a closed economy using Norwegian data. There is a large literature with a primary focus on the financial accelerator mechanism going through the balance sheet channel of firms, and some also focus on the less known, the exchange rate channel amplification mechanism. I will, however, focus on the financial accelerator within the housing sector and the effect going through collateral constraints. I wish to see how the financial accelerator applies to Norwegian data in a DSGE model incorporating heterogeneous consumers; households following a permanent income hypothesis (PIH) and households displaying a Rule-of-Thumb (ROT) type behavioural pattern. The financial accelerator theory postulates that positive real and monetary shocks to the economy that lead to increased asset prices will, through a collateral effect, also lead to increased consumption today. The mechanism in play here is as follows. When house prices increase, the net wealth of households with a mortgage increases as well. Households will then have more negotiation power and can demand lower interest rates or even withdraw equity through a Home Equity Loan. The increased purchasing power will then lead to increased consumption today. The amplification and propagation mechanism at work here is called the financial accelerator. I estimate a closed economy New Keynesian DSGE model using a Bayesian approach. I calibrate the relevant parameters and estimate the others for the period 1995Q1-2010Q4. I then move on to implement asset prices (residential and non-residential prices) into the monetary policy specification.

I find that the impulse responses are amplified when collateral effects are present. This is most clear when we look at monetary and real shocks since these types of shocks directly affect asset prices and hence affect the balance sheet of the households. I also take a closer look at the wage share of the unconstrained households. I believe that a reduction in this wage share proxies for increased ROT consumers or even the case of restricting the ease of credit unrelated to housing. I find that increased ROT type consumers amplify the shock and lead to a marginal effect on GDP, increased effect on real house prices and also increased effect on consumption when compared to the case of no collateral effects.

2 Defining the financial accelerator and financial frictions

2.1 The financial accelerator

Defining the financial accelerator is not an easy task, isolating the financial effect is not exactly a walk in the park either. Loosely spoken, the financial accelerator theory postulates that shocks that increase (decrease) the net worth of an agent also lead to an additional effect, other than the wealth effect, through the increased (decreased) credit worthiness of agents and hence to reduced (increased) cost of borrowing. The change in the cost of borrowing will then amplify and propagate the initial business cycle leading to more persistent and stronger effects on the general economy. Bernanke et al. (1996) refer to this amplification of initial shocks brought about by changes in credit-market conditions as the financial accelerator.

The Modigliani-Miller theorem states that when there are no market frictions, like complete markets with perfect information and no transaction costs, it is irrelevant how a corporation finances itself; be it by debt or equity. This is, nonetheless, a restricting assumption as without market frictions financial markets have no reason to exist. The recent financial crisis is a clear indicator that market frictions are in fact present and can have drastic consequences for the world economy. Modelling the real world as if there are no market frictions is a naïve point of view. The Financial accelerator is largely due to financial frictions arising from imperfect information such as asymmetric information leading to Principal – Agency problems. Asymmetric information is defined as a case where one party in a transaction has more information than the other. The corresponding agency problems are more severe when the incentives of the principal and the agent do not align.

An important channel financial crises affect the real economy is through the creditworthiness of borrowers. A borrower gets extra liquidity through posting collateral, i.e. the accessibility of collateral give support to credit extension. Posting collateral for a loan reduces the lender`s risk and therefore makes sure that the borrower (agent) and the lender (principal) both have the same incentives towards the collaboration. It is this risk that is given value in the market and its very own definition, of which we turn to next. Bernanke et al. (1999) introduce asymmetric information and agency costs in lending relationships, and hence, define a wedge between the opportunity cost of funds raised internally and the cost of funds raised externally, called the external finance premium (EFP). In other words it is the difference between financing a project internally, like withholding dividend pay-outs, and obtaining external financing, like a bank loan. Due to agency problems, obtaining external credit is almost always more expensive than internal finance; debt versus equity. This will in most cases be true unless the debt is fully collateralised. Hence, the external finance premium is in most cases a positive number. And as such, the external finance premium depends heavily on the financial position of the borrower; the premium charged is then said to be inversely related to the net worth of the borrower. The richer an agent is, i.e. the more collateral he can post, the less risk the lender takes on and will therefore require a lower premium. The other way around, if the borrower is in a dire financial position, the lender will charge a higher premium as he faces higher default risk, the so called “flight to quality”. A borrower in a better financial position has also greater incentives towards making better informed decisions and evaluating the risk accordingly and will therefore also require less monitoring costs. He is said to have more “skin in the game”.

Events that change financial and credit conditions of agents, like real or monetary shocks, are important in the propagation of the business cycle, i.e. it amplifies the initial effect into bigger static and dynamic multipliers in the different periods, as shown in Kiyotaki and Moore (1997). The oil crisis in the 70`s are often used as an example of small initial shocks that led to persistent fluctuations. Changes in financial conditions may intensify the effect of monetary policy on the economy; this is often called the credit channel of the monetary-policy transmission.

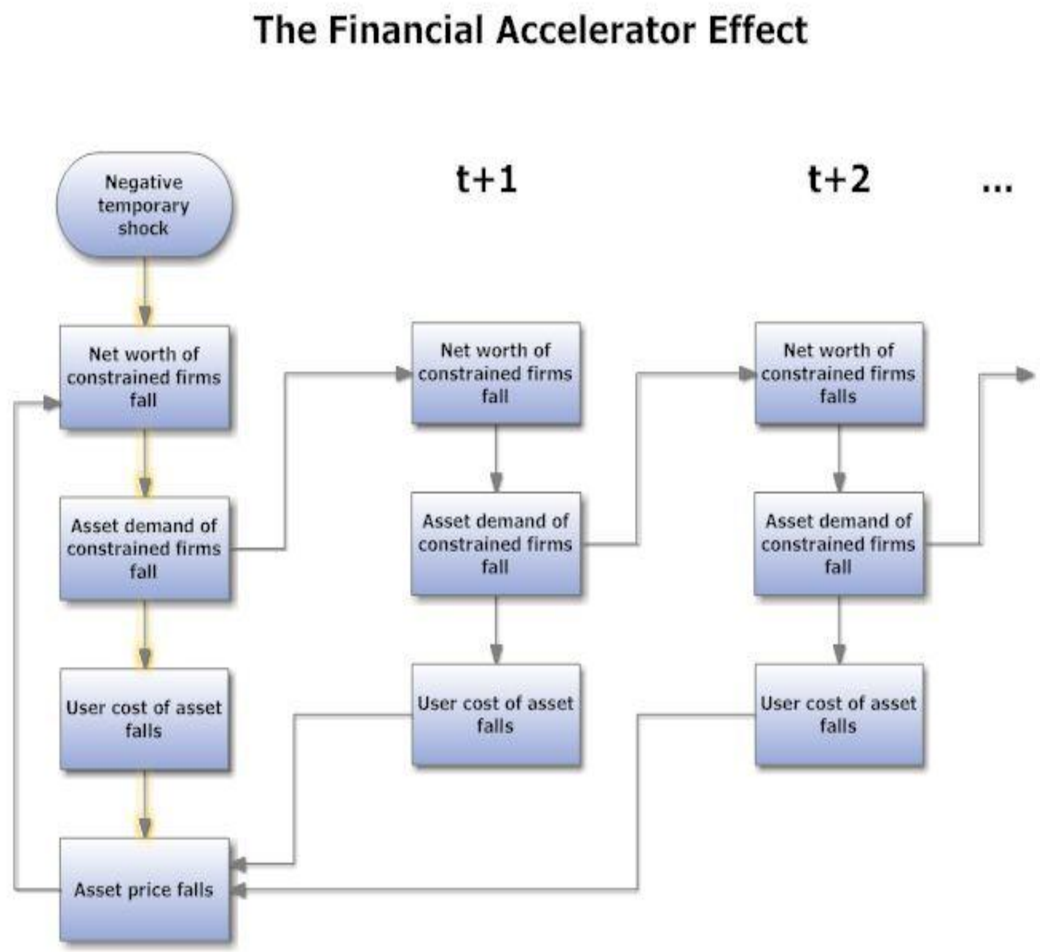

Figure 1 – Illustrated the financial accelerator effect of a negative temporary productivity shock to the economy.

It is through this key term that the amplification mechanism comes in to effect. Kiyotaki and Moore (1997) show that a negative temporary productivity shock to the economy will lead to reduction in activity, consumption, investment, and through a multiplier effect, an additional worsening of activity. This is known as a static multiplier. The negative temporary shock has then led to reduced asset prices. This effect goes through the reduction in the net worth of liquidity constrained firms and households → asset demand falling → user cost of assets fall since the marginal productivity falls for the liquidity constrained agents.

The authors also incorporate a dynamic multiplier mechanism that comes into play in the second period and stays around for several other periods. The asset prices fall further due to the reduced asset in the previous period → net worth of constrained firms and households fall yet again (increasing the EFP) because of higher default probability → further fall in asset demand → further fall in user cost, and this goes on and on until the small temporary shock to the economy has been dramatically increased, propagated and amplified the business cycle. This affects the first period asset price because the asset price is simply the discounted value of future user costs.

A reasonable assumption is that net worth is procyclical, seeing that profits and asset prices are generally greater in good times. The external finance premium, on the other hand, is generally considered countercyclical as it amplifies the cycle through the accelerator effect on aggregates like investment, production and consumption. Gelain (2010), however, casts doubt on the generally assumed countercyclicality of the EFP. He found out that depending on the shock hitting the economy, the EFP may in fact turn out to be procyclical. While agency costs in credit markets will generally be countercyclical since a monetary relaxation that leads to lower interest rates also generates a real economic boom that improves the balance sheets of firms. This then lowers agency costs and thereby raises the efficiency of allocation.

2.2 The financial accelerator in the housing sector

Empirical findings suggest that there is an economic link to house prices and consumption, suggesting that they move together. If increases in housing prices lead to increased housing transactions then this link may be explained by the increased demand for housing appliances; like furniture and curtains for instance. Housing goods and consumption goods are likely to increase if agents are rather optimistic regarding future economic prospects. This link is, perhaps, best explained through the credit market effect, suggesting the importance of the collateral effect in obtaining credit from intermediaries. There is every reason to believe that the financial accelerator also applies to households and their consumption of housing and housing services. It is this latter effect that gives rise to the term “the financial accelerator theorem in the market for housing.” Households generally have most of their wealth tied up in the house they own and are therefore quite perceptible to shocks and events that change their net-worth. Aoki et al. (2004) argue that in the case of financial assets, an increase in the price would lead to an outward budgetary shift. While in the case of house prices on the other hand, this wealth effect may not be present. They notice that even in a finitely lived household, an increase in house prices just leads to a redistribution away from a first time borrower to the last-time seller, not an increase in aggregate per se. And since most home owners live in their own house they optimise until the benefits of an increase in house price is directly offset by the opportunity costs of housing services.

Quite like firms, households face an external finance premium that is inversely related to their financial position as well. The higher the loan-to-value (henceforth LTV) ratio is the higher the premium the households face. The financial accelerator is in fact amplifying the effect to account for more than the traditional theory around wealth effects suggest. Collateral is fairly important as consumers are in reality using the value of their house to obtain higher consumption through increased borrowing to the face value of the house, so called mortgage equity withdrawal (MEW). Soaring house prices lead to more collateral being available to the households and therefore more money can be borrowed from intermediaries to finance increased consumption and investment. House prices are in this respect exceedingly cyclical, leading to large discrepancies in the net worth of households and then to large discrepancy in consumption through the MEW effect. Another important mechanism to remember is that households that are not able, or willing, to withdraw equity may still benefit from increasing housing prices due to decreasing LTV ratios, and hence, benefit from lower interest rate spreads. The reduced cost of borrowing may then signal households to consume more or perhaps even take up more loans. The EFP will here benefit them in good times, and of course harm their financial position in bad times. An underlying assumption within MEW is that households are said to be smoothing consumption over their lifetime, so called permanent income hypothesis (PIH). Empirically, however, there is evidence for some households actually behaving according to a rule-of-thumb/constrained manner (see Gali et al. (2004)). I will of course embellish on this in later chapters.

Is there evidence for rising housing prices having led to the consumption boom of the last decades? In Iacoviello (2005), the author lists several elasticities found from other papers suggesting positive long-run elasticities of consumption to housing prices of around 0,06 for a panel of US data, and a long-run elasticity of consumption to housing wealth of 0,08. He raises concern regarding the life-cycle model; whether it is being too constrained in the belief that rising housing prices lead to gains being equally distributed, when we should in fact have unchanged demand with the assumption of same propensity to consume for both types of consumers. In fact, according to Iacoviello, the impatient households will, ceteris paribus, end up increasing consumption more than their patient counterparts due to their more impatient nature.

The housing sector is a tricky thing to isolate. First of all, just like other assets households hold, an increase in house prices leads to a direct wealth effect and should according to micro theory lead to increased consumption. It is, however, not as easy as that. Campbell and Cocco (2007) noticed that the theoretical rationale for a large housing wealth effect is rather vague. They go on to further argue for their view: "*If we define financial wealth as the sum of liquid financial assets and the value of real estate minus debt outstanding, it is clear that an increase in house prices leads to an increase in homeowners` financial wealth. But this doesn`t necessarily mean that their real wealth is also higher.*"

Housing is considered a consumption good, and therefore an increase in house prices must be seen as increased benefits of not having to pay higher rent in the rental market. In this view there are no real wealth effects and should consequently not have any effect on consumption either, conditioned of course on substitution effects being absent as well. Second, as already argued above, the borrowing constrained households wish to withdraw the increased equity of the house to smooth consumption over time, and thereby increasing consumption now. According to a household survey in Norway completed in 2006, about 4 out of 10 households are actually willing to do a Mortgage Equity Withdrawal, MEW[1]. Half of them do this to increase their consumption today, one quarter do so to transfer funds to their heirs, and one in ten wish to save the money instead.

Most mortgage contracts in Norway are in fact variable mortgage rates. Unlike the case of the United States and Denmark, the cost of refinancing a mortgage contract in Norway are slightly higher and therefore allows the borrower to a lesser degree to adjust mortgage rates when interest rates fall. We could look into how big effect monetary policy has on different households with different mortgage contracts. Theory suggests that Norway, which has a higher fraction of homeowners with flexible interest rates contracts, will be more susceptible to changes in monetary policy than in the US, where a fixed interest rate is more common.

"…In countries like the United Kingdom, for example, where most mortgages have adjustable rates, changes in short-term interest rates (whether induced by monetary policy or some other factor) have an almost immediate effect on household cash flows. If household cash flows affect access to credit, then consumer spending may react relatively quickly. In an economy where most mortgages carry fixed rates, such as the United States, that channel of effect may be more muted." Bernanke (2007)

Rubio (2009) reach the same conclusion as Bernanke in her study of variable versus fixed rates mortgage contracts.

One can also distinguish between predictable and unpredictable changes in house prices. Campbell and Cocco (2007) argue that forward looking households may in fact realise the wealth effects of house price changes well in advance of the actual change, as soon as they form the expectation of the change coming. A predictable change, however, will still help relax the borrowing constraints, even if there is no wealth effect. The reason is that the predictable change has already been anticipated. This is in contradiction to the permanent income hypothesis which postulates that consumption is only affected by unpredictable changes in income. This will of course complicate the effect considerably, and as such will require two assumptions. First, only when increased house prices are realised will housing become available as collateral, and not when it can be predicted. Second, and lastly, borrowing capacity depends on current house prices, and not on the purchase price of the

[1] The survey and the report is found here, albeit in Norwegian: http://www.sparebankforeningen.no/id/13456.1

house. They also estimate the house price elasticities of consumption both for an old cohort and for younger consumers. The main conclusion to be had from this paper is that the old have a higher elasticity of consumption, while the younger consumers have an elasticity that is insignificantly different from zero. This may be due to the notion that increased house prices will lead to younger/first-time-buyers ending up with a lot less liquidity, and will not be able to achieve the high consumption the permanent income hypothesis suggests. This leads to the conclusion that as the baby boom grow older, the old will stand for a greater portion of the population, and then consumption will also be more responsive to changes in house prices. However important as this fact may be, it is also something I will disregard in this paper due to the complications of modelling it in my highly stylised model.

Figure 2 – Financial accelerator in the housing market, only static effects are displayed.

What I will focus on here will be mainly on unpredictable house price movements, on the collateral effect, and how this may be affected by borrowing constraints; leading to changes in the borrowing opportunities of households.

3 Key Characteristics of the Housing Sector

3.1 Household saving and investment

In this section I will take a closer look at the savings behaviour among Norwegian households and do a cross-country comparison of the savings rate and investment choice, and try to characterise Norwegian households' asset holdings and liabilities. Most importantly I will look at the how the acquired Home Equity Loan is spent among the households; saving the proceeds or spending it on increased consumption today.

Figure 3 depicts the savings rate during the last two decades for Norwegian households and several other countries that it is natural to compare us with. Norwegian households save in several different ways. Norwegian saving ratio was in the early 2000s quite volatile in comparison to the other countries saving ratios. Notice also the large drop in the savings rate from 10% in 2005 to 0.1% in 2006, only to rise again to around 7% in 2010. This big fall in the saving ratio was mostly because of the change in dividend tax that was announced in 2006.

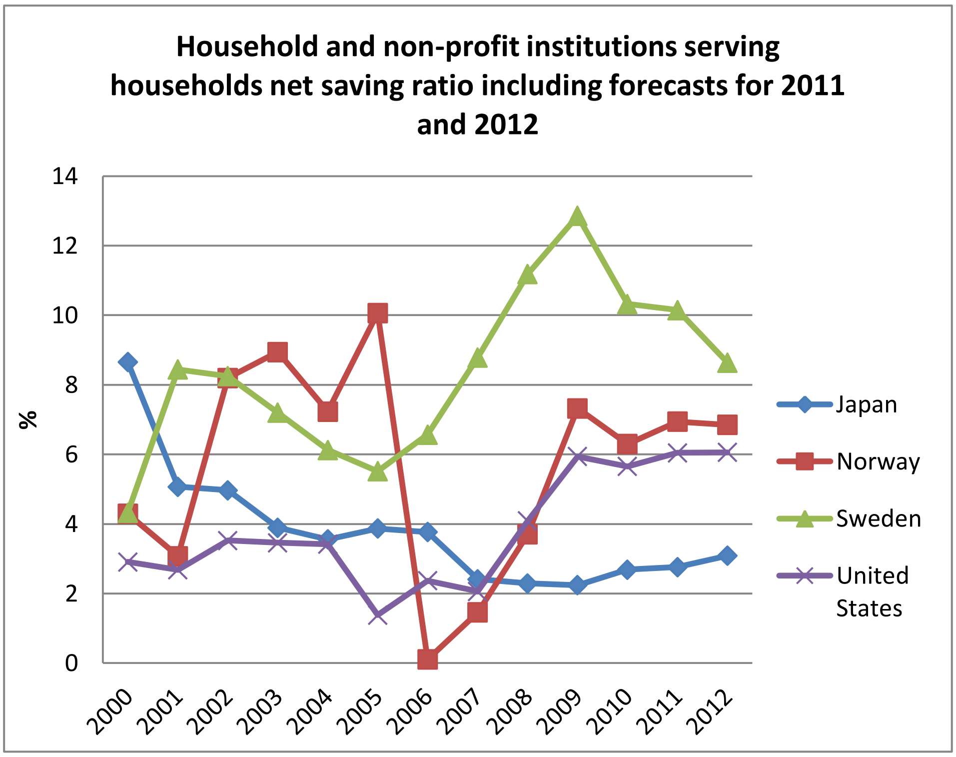

Figure 3 – Cross-country savings rates. Data: OECD, Economic Outlook No. 88

Saving is defined as the net amount of labour income, net capital income and net transfers that is not consumed. For the Norwegian population the government is doing most of the saving as ridiculous amounts of money are extracted from the North Sea every day. In fact, 4 out of 5

NOK saved are done by the government. This saving is, however, not depicted in figure 3 as it only depicts households and non-profit institutions. The government's claims have increased a lot more than its obligations, while the households claim versus obligations has been relatively constant. A significant portion of household wealth is tied to deposit accounts and claims to money from insurance and pension funds; of which are highly illiquid in the short and medium term. The households are investing only a small portion of their wealth in the stock market, and are therefore to a certain degree not exposed to the volatility in the stock market. Norwegian households saving ratio was negative in the 80`s and turned positive and relatively stable in the 90`s. Last decade it turned more volatile and reached a level of 7,4% in 2010. A concerning factor regarding the recent developments in the financial statements of households is that the growth in income has lately not kept up with the growth in household debt. The last decade brought about a period of low interest rates and liberal lending practices.

Norwegian households save in several different respects. While until recently only a small portion saved in the stock market, an increasing part of the population is now also investing in shares and bonds. We also see a trend towards more complicated portfolios as well. This may be due to the need for diversification of risk or even because of the ever-lasting search for yield due to low interest rates in the aftermath of the financial turmoil. The Norwegian households are still heavily built up of "safe" investments, as more than half of the financial assets of the households are tied to housing. Housing, as an asset, is in itself rather safe investment for the individual household, but it is also fundamentally unsafe for the general economy. As will be elaborated more in later chapters.

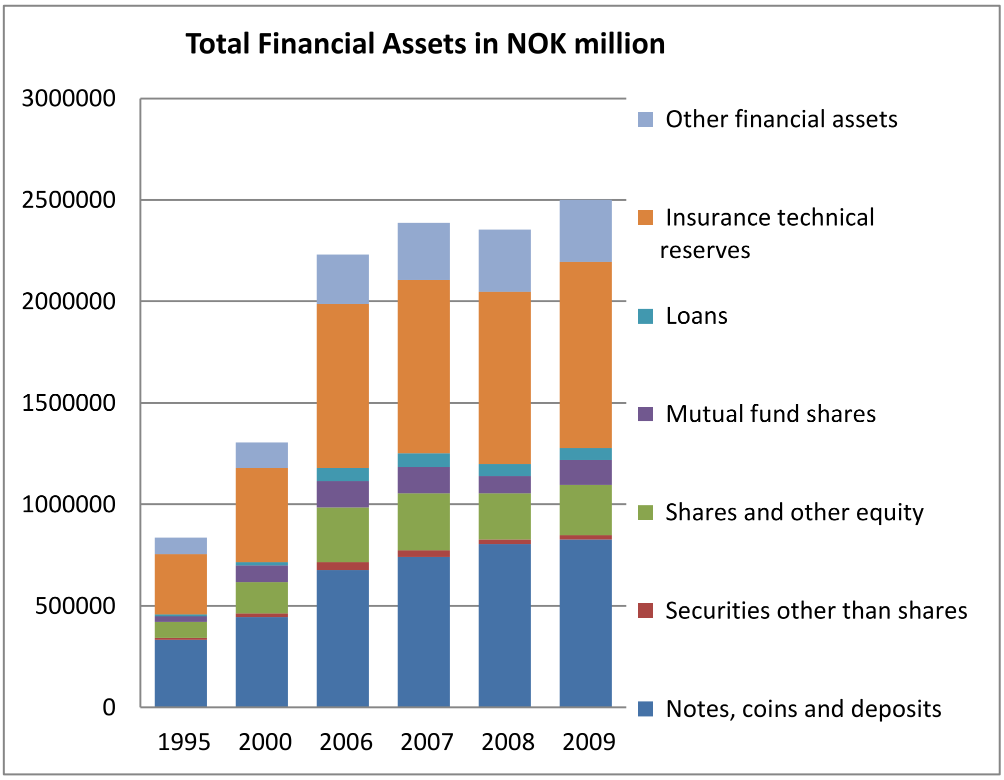

Figure 4 – Total financial assets for Norwegian household

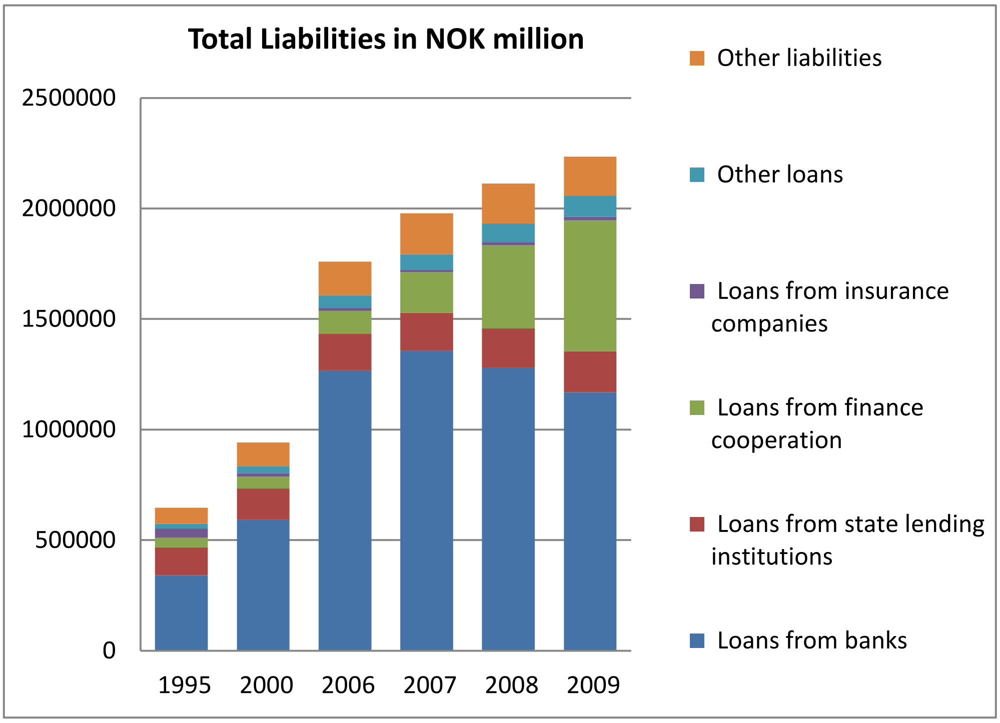

Figure 4 – Financial liabilities of Norwegian households[2]

Figure 6 shows the structure of the debt for Norwegian households over a 15 year period. Mortgage backed loans and other loans using homes as collateral stand for approximately 71% of the household debt. One of the main contributors for this development is the increased popularity of Home Equity Loans (HEL). This is also the channel through which households are withdrawing money from the housing market, the so called MEW. In March 2010 the Financial Supervisory Authority of Norway (FSA), Finanstilsynet (2011), established guidelines they suggested the banks to follow. They recommended that the LTV ratio should generally not exceed 90% on market value of the home, and in the case of HEL this rate should be fixed at 75%. The regulatory authorities gather data from annual bank surveys they conduct. Based on these surveys they found that in 2010 approximately 21% of mortgages had a LTV ratio exceeding 90%, and shockingly 9% of the mortgages had in reality an outstanding mortgage above the home market value. The mortgages the households are getting are in almost all cases flexible interest rate contracts, and an increasing proportion include a no annuity period. Considering HEL, 89% of the cases in 2010 were under the 75% the authorities suggested, implying a sound financial state of the economy. The survey also concludes that a large portion of the households withdrawing equity from their homes are in fact spending the proceeds on buying a car, boat or even a cabin. HELs are, according to the report, used mostly on goods other than housing services and investment in own home. It is however alarming that the increase in HEL usage has also led to decreasing down payments of the total outstanding mortgages in Norway.

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[2] The table with the associated values for graph 4 and 5 can be found here, albeit in Norwegian: http://www.ssb.no/emner/08/05/10/oa/201101/08hushold.pdf

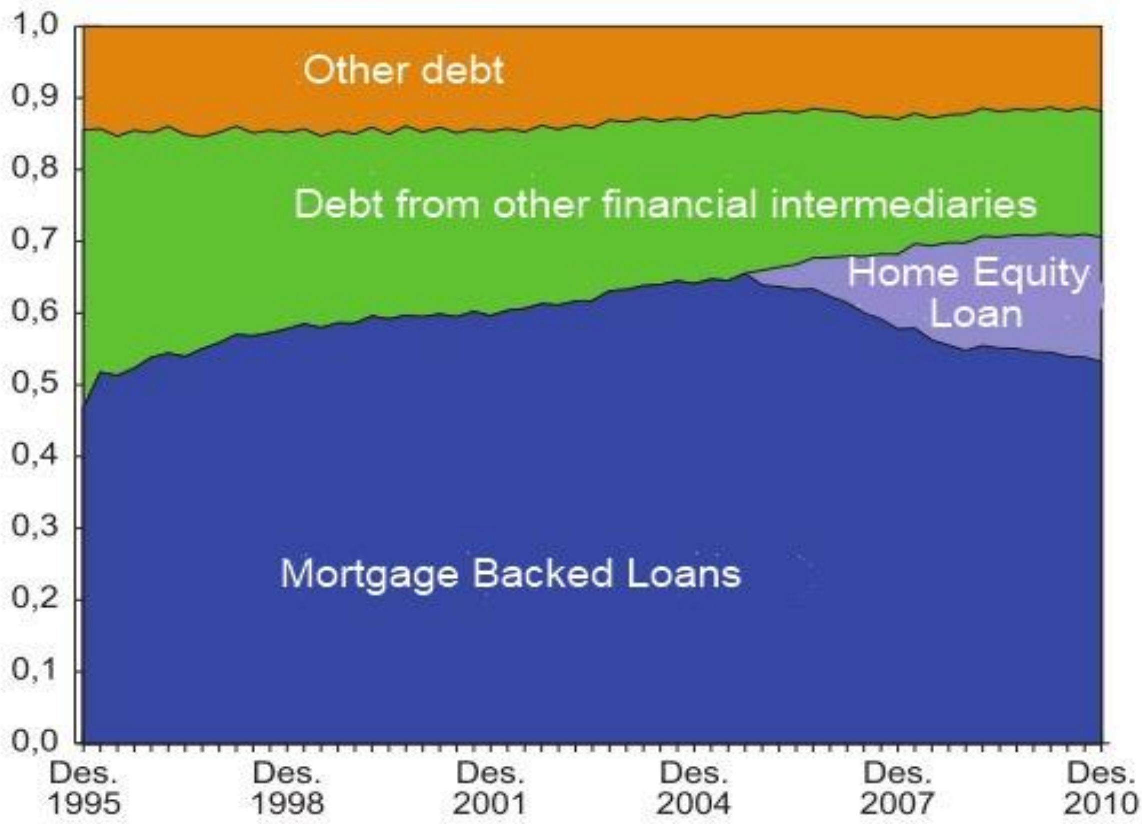

Figure 6 – Graph depicting the components of household liabilities over a 15 year period. Source: SSB.

3.2 Developments in the housing sector

The Housing market has increased fourfold since the 90`s. Early 2011, it was about 7% higher than the peak in 2008, the weeks prior to the Lehman collapse and the beginning of the financial crisis that led to crashing housing markets in several different parts of the world. In comparison, the CPI has only increased by 45% during this same period, and the costs of construction about 82%. Clearly, the price increase in the housing sector is not even remotely due to construction costs only. One might argue that because of people's aversion towards selling at a loss, house prices are generally sticky on the way down, as opposed when the market is booming. Norway has one of the most deregulated housing markets in Europe as well. Sweden, Denmark, United Kingdom, Netherlands and Austria, all have government regulated housing markets. All of which provide price regulated government constructed housing. Norwegian authorities deregulated a heavily regulated housing market up until the 1980s leading to people's savings and private equity entering the equation. The housing market was liberalized; the prohibition against pre-emptive regulation and other price regulations was launched, as well as selective instruments directed towards first-time buyers.

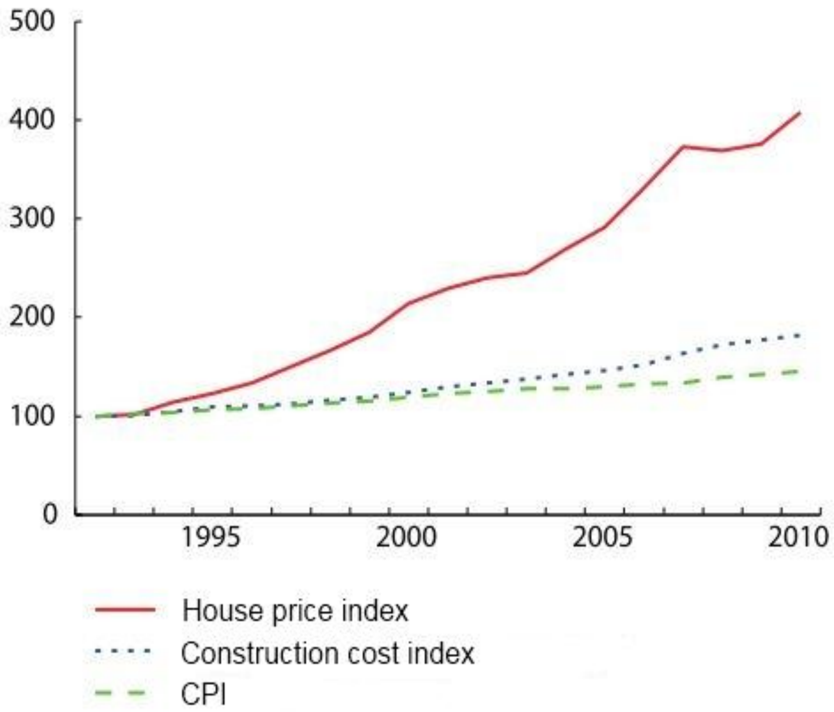

Figure 7 – The housing market in a 20 year perspective. Source: SSB, Economic analysis 1/2011.

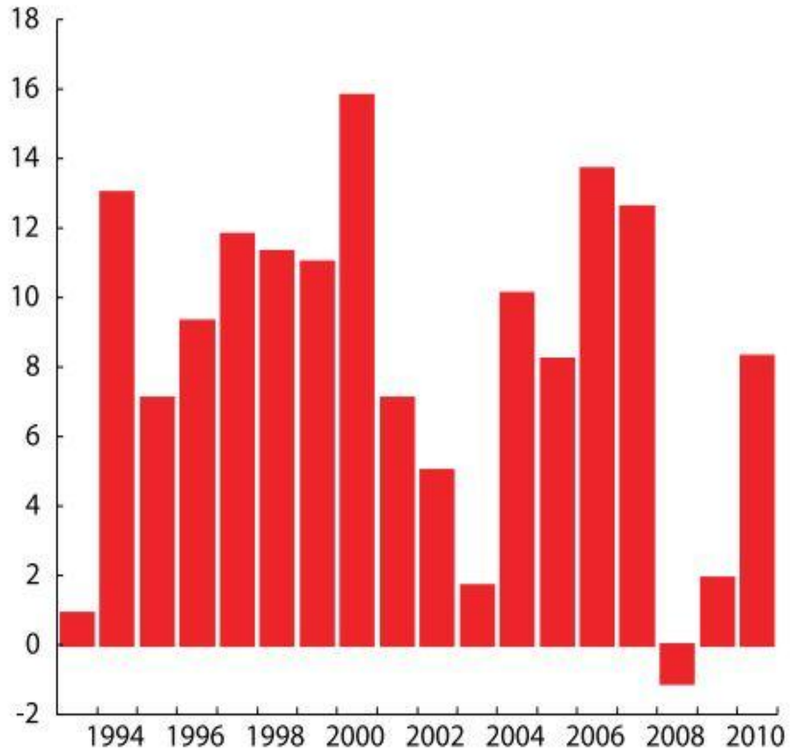

Figure 8 – Percentage change in house prices on a year to year basis. Source: SSB, Economic analysis report 1/2011.

Graph 8 depicts the percentage deviation on a year to year basis. As we clearly see from the graph, in the period of the boom preceding the dot-com bubble the growth in the housing market was quite high, 14% in 2006 and 13% in 2007. The financial crisis brought about a year of negative growth, only to pick up again a year later.

Graphs 9 and 10 compare the Norwegian housing market with several countries it is natural for us to compare us with. The Real percentage change, inflation adjusted, shows a similar picture, but here Norway is rather volatile and has had a bigger growth in real house prices than the other countries in the figure. In 2008 and 2009 the housing market in several parts of the world was characterised by a standstill. Recently, however, in Norway we see that the housing market has picked up again. High unemployment rates, pessimistic expectations regarding future growth and debt issues still characterise the housing market in these countries. In the US a high fraction of default rates and REPO rates has increased the supply of homes depicting a still gloomy housing market. The Swedish housing market has lately picked up like the Norwegian housing market and the FSA in Sweden has prepared guidelines towards reducing LTV ratios. Iacoviello (2005) argues that the rising house prices have kept consumption growth high for the last couple of decades in the US. This might be the case for Norway as well, although the MEW channel is a relatively new feature for Norwegian consumers.

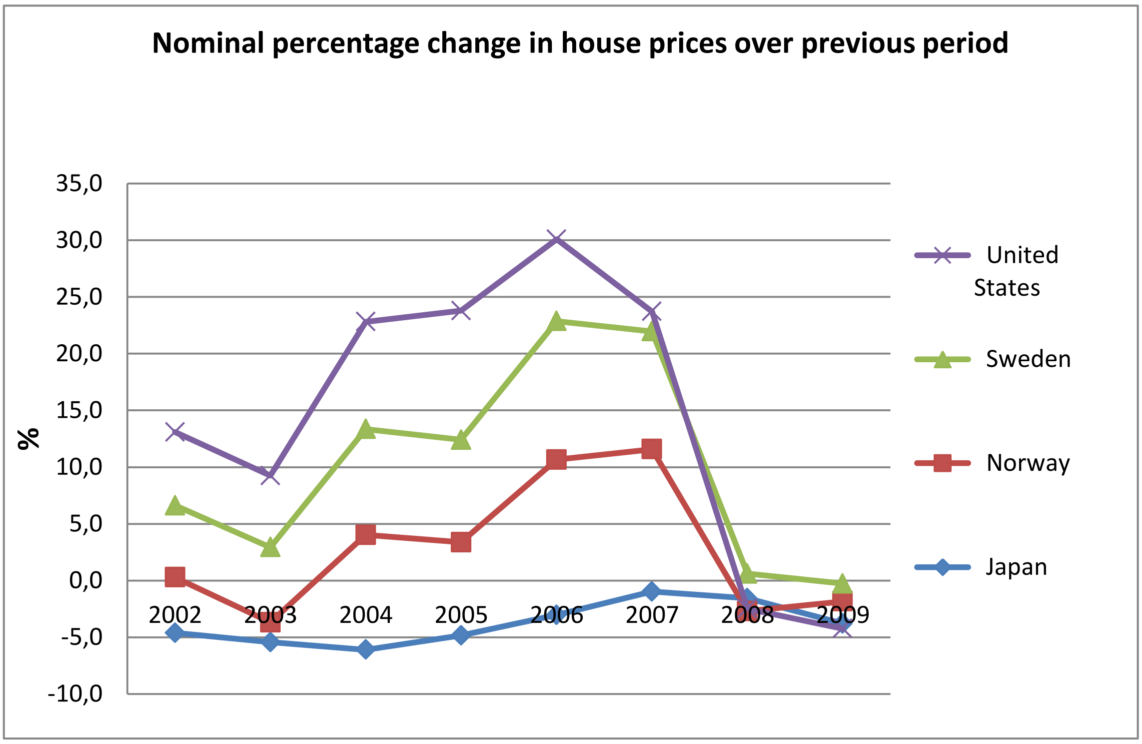

Figure 9 – Cross-country comparison of nominal changes in house prices over previous period. Source: OECD.

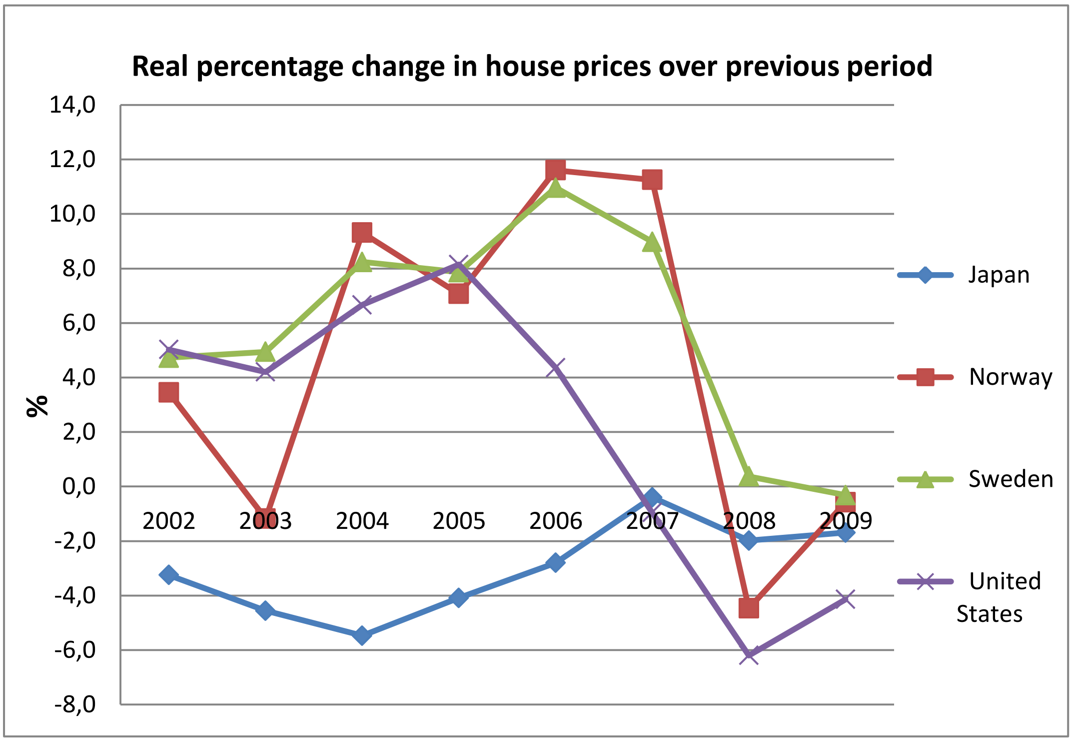

Figure 10 – Cross-country comparison of real changes in house prices over previous period. Source: OECD

3.3 Determinants of the housing market

One may ask which factors play an important role for the developments in the housing market. In the short run the growth in the housing market may be determined by, as indicated by Tsatsaronis and Zhu (2004) as well:

- Availability, cost and flexibility of debt financing
- Number of potential housing consumers and their financial resources and tastes
- Transaction costs such as inheritance tax, registration duties, and the level of value added tax (VAT)
- Different ways of measuring user cost of housing that account for deductibility of mortgage interest rates
- Uncertainty, periods of high volatility in the housing market will often lead to reduced future predictions and more cautious construction behaviour
- Length of planning and construction stages

- Existing land and planning systems

In the longer term the housing market is determined by:

- Average level of the interest rate set by the central bank
- Demographics
- Household disposable income
- Permanent changes in the tax system that encourages investing in housing rather than other financial assets
- Availability and cost of land
- Production costs and the cost of investments that aim to improve the quality of existing housing stock

Tsatsaronis and Zhu (2004) use a structural vector autoregression (SVAR) framework on cross country data and find that the most prominent explanation for what drives house prices is the inflation rate. Inflation is the driver of housing prices and on average it explains almost half of the total variation in the house prices at the five-year horizon. Being even larger in the short run, almost 90% of the variation is driven by inflation. The authors reason that this may be due to the interlinkage of housing; acting both as a consumption good and an investment good. Households are believed to hedge against risks of rising inflation through real estate. The BIS authors also argue that a second explanation for inflation being such an important driver of housing prices is because inflation affects the cost of mortgage financing and it may also act as a proxy for the prevailing financing conditions.

The second most important factors determining the developments in the housing market are: spreads, bank credit and short-term interest rates. The authors conclude that they are equally important and that they together stand for approximately one third of the variation in the housing market in the long run. Income, on the other side, is of shockingly small relevance in explaining the variations. In other words, it matters less what the income of the household is as long as the mortgage payments are low enough when deciding whether to purchase a new home or not. This is also the case for Norwegian consumers. What matters is the capability of households in taking on and servicing new debt, and to a lesser degree the income of the households.

In countries with more flexible interest rate mortgage contracts and more market based property valuation practices for loan valuation, the authors find evidence for a stronger feedback mechanism from property prices to credit growth. As is also the case for Norway, since most of these determinants are present in the Norwegian housing market. In fact, only 3% of total mortgages in 2010 were on fixed rate contracts.

One might wonder if housing prices need to decrease at all and if they generally do so in practice. The housing market was a contributing factor in dampening the slowdown in global activity early in the 2000s, and now in the aftermath of the credit crunch we see similar tendencies in several parts of the world as house prices continue to soar. In a study by Borio and McGuire (2004) the authors find that equity price peaks have considerable predictive power for subsequent housing price peaks, in a cross-country study for the period 1970-early 2000s. This indicates perhaps a boom and bust cycle in the housing market that feeds onto itself. As opposed to imposing a “natura non facit saltum” condition on housing, one generally finds that the housing market instead grows at a slower pace as the economy recovers after a recession, or even a downturn in production. The authors also check whether this predictive power is somewhat reduced if output growth, unemployment and interest rates are included. They find that:

“…housing price peaks have tended to follow periods of comparatively strong economic activity …For example, the coefficients on the lag of GDP growth, while not always individually significant when multiple lags are included, indicate that the overall effect is positive and statistically significant. Similarly, the effect of unemployment is negative, implying that a fall in unemployment in the periods preceding a peak in equity prices leads to a higher probability of experiencing a peak in housing prices in the quarters ahead. …increases in interest rates were a factor bringing the rise in housing prices to a halt”

Borio and McGuire (2004) pp. 86 - 87

They come to the conclusion that the predictive content of this relationship between equity and housing is fairly robust to the presence of other macro economic variables as well.

Housing demand takes up most of the literature on reasons why we have booms and bust. Lately, nevertheless, there has been an increasing concern over whether the researchers are too narrowly concentrating on the demand side. Clearly, one must understand the supply side as well if one wants to determine the reasons for booms and busts in the economy. There is a concern that there are too few homes being built where people want to live, and unless this is corrected the prices will continue to soar. New government regulation, together with new energy requirements launched in July 2010, put heavy restrictions on the standard of new homes and this made new homes more costly than with previous regulation.

3.4 Similarities and differences between housing and other financial assets

I have already discussed how Norwegian households have a lot of their wealth tied up in housing and how some see it as an investment good as well, but how closely related is the housing market to other financial assets, e.g. shares and other equity? What are the similarities and differences? These are the questions I wish to address now.

There is a close relationship between equity prices and housing prices. As already noted, housing price peaks tend to come after an equity price peak, and also after a beneficial economic environment. Traditional economic theory states that both equity and housing are somewhat similar long lived assets, in the sense that they both are claims to goods and services. They both have several determinants in common. Both will benefit from comparatively strong advantages in economic activity. At the same time they are different in several ways. First, real estate is more illiquid than private equity; people generally don't borrow money to invest in shares and bonds and if they do, the leverage ratio is way lower than for housing. Second, we cannot always determine if housing is an investment good rather than consumption good. There are multiple reasons why people buy homes. Wanting to provide a safe environment for their offspring, having more control of their living space and financial motives, such as return, are some of them. This mixture leads to problems for the financial system because if housing was truly a consumption good, increasing the price should then lead to falling demand. As a financial asset, the increase in price actually motions a buy now signal. Third, Norwegian houses are not widely traded internationally. Hence, the Norwegian consumers cannot realise, in aggregate, their capital gains and increase their consumption therein. Fourth, differing economic environments may shift demand for one asset in favour of the other. We are here talking about portfolio shifts that drive a wedge between this relationship. Lastly, there is no way someone who believes that the housing market is overpriced may benefit from this by short-selling the asset and this therefore leads to the momentum in the property market. The short-comings of the market to provide a possibility for short-selling in the housing market may in fact be leading to the bubbles in the housing market.

3.5 Bubbles

What makes houses such an unsafe asset for the economy? It is perhaps the most dangerous asset of all; looking at the absolute size of the asset class.

> "The five big banking blow-ups in the rich world before the latest crisis (Spain in the 1970s, Norway in the 1980s and Sweden, Finland and Japan in the 1990s) had property at their heart."[3]

Houses are the most important single asset of most households, but it is also the backbone of the financial intermediaries since the value of real estate is incorporated in their portfolios. In

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[3] "A special report on property: Bricks and slaughter." From the online version of The Economist, http://www.economist.com/node/18250385

fact, there is a double leverage as both the banks and property are leveraged. House prices are in effect not only affecting the business cycle through the financial accelerator, but they also influence the performance of the financial sector. It is this interlinkage that determines the soundness of the economy.

Considering the Norwegian economy, a reasonable question to ask is whether there are bubble tendencies in Norway. I will not speculate whether the housing market is experiencing a bubble. It is rather difficult to assess whether the price increases are coming from underlying economic fundamentals or perhaps irrational exuberance. While western countries are experiencing deflating house prices in the aftermath of the financial crisis (Norway and Sweden being notable exceptions), eastern countries are essentially still experiencing ever-increasing house prices, China is a good example of this. The close ties the housing market has with the financial sector leads to crises that affect the whole economy, and this boils down to an extreme bill that is disproportionately shared among the population and among countries. Newspapers in Norway have long been monitoring the developments in the housing market. There is a growing concern there is a shortage of houses and that building new homes is quite expensive, in fact construction of new homes has not been this low in 100 years, pushing the prices further up the sky. We have, nonetheless, seen that construction costs did not play a big role in the fourfold increase in house prices from 1995-2010. House prices are predicted to increase by another 30% by 2014. Norges Bank has declared it is going to double its current policy rate by 2013-14, and although this should in practice lead to lower asset prices, the fact remains that higher rates will also lead to lower profitability in the construction of new homes, due to higher opportunity cost. Clearly, the market is not learning from its own mistakes, and time and again one ends up thinking that “this time it`s different”, but it rarely is. And if the market is not going to regulate and fix its own problems, then that leaves the government with the unpopular job of pulling the strings. The authorities have several ways of giving disincentives towards investing in an already inflated housing market. First, institutional changes like altering the tax system towards making housing a less attractive investment object. Svein Gjedrem, former governor of Norges Bank, has long been a proponent for reforming the taxation of housing to counter credit cycles and achieve a more stable housing market; proclaiming that increased taxation of homes, in a similar manner as other financial assets, will lead to a dampening effect on housing prices. Second, the mortgage financing is a cause for concern. The subprime crisis originated and escalated due to credit being to easy at hand, and this drove up the prices creating a bubble that burst. This led to falling housing prices, and in some places the housing market is still characterised by great scepticism regarding future economic prospects, like USA. There are some drawbacks, however, in changing the ease of credit. First-time borrowers and self-employed will suffer because of this, and this may lead them to find alternative, and perhaps more expensive, financing.

Third, macroprudential regulation works great in theory, but is rather hard to implement in practice. Generally bubbles are known to be a fact only when they burst. These are instruments like changing the LTV ratio according to the current cycle, changing the reserve requirements and thereby reducing the amount of credit that banks can lend out. Angelini et al. (2011) find that macroprudential policy, like the LTV ratio, contribute little in normal times, but have substantial macroeconomic advantages in the case of adverse shocks. Catte et al. (2010) instead ask:

> *"Was US monetary policy too expansionary for too long in the wake of the 2001 recession? Would a tighter monetary stance have prevented (or at least contained) the housing bubble?"* Catte et al. (2010) pp. 6

They reach the conclusion that regulatory failures, low perceived risk and abundant liquidity helped inflate the price bubble prior to the 2003-2007 period. Svenson (2004), conversely, takes on a different approach. He claims that asset prices should generally not be the concern of the monetary authorities unless they have an impact on target variables, inflation and output gap.

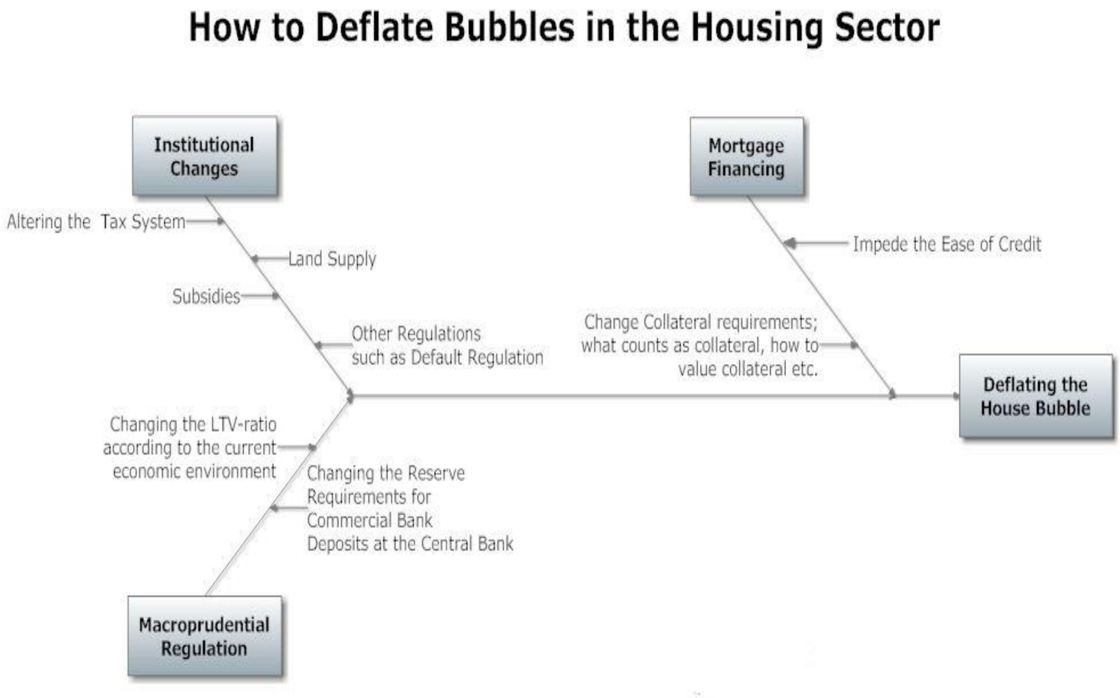


Figure 11 – Different measures normally undertaken in the case of housing price bubbles

4 Modelling Housing Spillovers

4.1 Current modelling approaches and monetary policy rules

Dynamic stochastic general equilibrium models are micro-founded optimisation models based on rational expectations of agents at the micro level. They have, nevertheless, grown in popularity in macro economics the last couple of decades and are now widely used in central banks. Using a general equilibrium framework, how does one go about incorporating borrowing and lending, without losing manageability and comparability with the benchmark macro models? Modelling the dynamic optimisation problem for heterogeneous households under liquidity constraints without losing the distinctive features of the credit channel, is rather complex. And by using a representative agent model we will not even have any lending in equilibrium. In other words, we want to incorporate liquidity constraints for heterogeneous households in a simplistic model and still be able to generate useful conclusions. When studying household savings behaviour many studies have resulted in using an overlapping generation's model to ensure both lending and borrowing occurs in equilibrium. Another frequently used model is the separation of the households into two behavioural types. We distinguish between a patient and an impatient group; one following a Permanent Income hypothesis and one Rule-of-thumb consumer type. This separation makes the model significantly simpler without losing the essence of the financial accelerator mechanism.

Aoki et al. (2004) study the interlinkage between the housing market and the general economy and postulate whether house prices merely reflect the macroeconomic conditions, or if there are indeed important feedback effects from house prices to other economic variables. The authors consider two behavioural types of households, homeowners and consumers. The homeowners buy houses with private equity and borrow from financial intermediaries, facing an external finance premium. The consumers consume goods and housing services. They rent housing services from the homeowners and supply their labour to a competitive labour market. The producers of the consumption good follow a sticky pricing regime, as is standard in the New Keynesian framework. They conclude that an expansionary monetary policy shock leads to increased housing demand, increased housing prices and therefore increased net worth of homeowners. The increase in net worth reduces the external finance premium and this then leads to a further increase in housing demand, and through a spillover effect to increased consumption. Aoki et al. (2004) argue further that a deregulated mortgage market will to lesser extent have an effect on housing prices, while the effect on consumption will be amplified.

Iacoviello (2005) setup the model with two key characteristics that define his work; collateral constraints, for firms and households, tied to real estate values, and nominal debt. Quite like Christensen and Dibs (2008) Iacoviello finds that supply shocks decelerate the economy, and demand shocks work the opposite way, amplifying and propagating the shocks. He concludes with the notion that there is little to be gained by a monetary authority actively seeking to stabilise output and inflation through responding to movements in asset prices, and that implementing nominal debt actually improves the output-inflation variance trade-off for the central banks since it acts as redistributing wealth between borrowers and lenders.

Mendicino and Pescatori (2005) try to find a link between the design of an optimal monetary policy rule and movements in housing prices. Unlike Iacoviello and Neri (2010) the authors direct attention to the welfare of the lenders and the borrowers. Like most other authors in this field of research, Mendicino and Pescatori focus on the households` sector instead of regarding housing as just another asset in the portfolio of households. In doing so, the authors find out how housing prices could be a variable of interest for the interest rate setting authority, instead of just looking at general movements in generic asset prices. Ibid. set up a simple model with two distinctive household types, a monopolistic competitive good producing firm with sticky pricing, and a monetary authority. Mendicino and Pescatori reach the conclusion that targeting housing prices for the monetary authority is welfare reducing. This result is in contrast to both Iacoviello and Neri (2010), and Faia and Monacelli (2004) in a different study.

Christensen and Dibs (2008) estimate a closed market DSGE model with rigidities such as sticky prices, capital adjustment costs and financial frictions. They embed a model with these rigidities and show that the financial accelerator improves the model`s fit with the data. They find that incorporating a financial accelerator actually reduces the effect on investment when considering a supply shock, it amplifies and propagates demand shocks and plays an important role in the transmission of monetary shocks. They also find that the same effect is rather miniscule on output, but this is mainly due to the monetary authorities reacting aggressively to output fluctuations in order to stabilize the economy. They also use a representative agent model, and in doing so they focus on the financial accelerator going through the balance sheet of firms instead of through housing prices.

Kannan et al. (2009) start off by asking several questions regarding the role of the monetary authority in a model with house price booms. They also ascertain whether the central bank should also focus on asset prices as well as CPI and output gap in a similar manner as Mendicino and Pescatori, and what I will do in later chapters. It is not always the case that the central bank can react to changes in different economic variables; take for example a state of high inflation and low economic activity. They therefore also consider the use of a macroprudential policy tool alone, or together with the monetary policy tool already in use, and its impact on the economy after a shock. Ibid. use a similar model as in the aforementioned papers. They find that when considering a demand shock to the economy, the monetary policy tool and a macroprudential policy tool can, and will, help to stabilise the economy. They notice that a macroprudential policy tool is unambiguously useful when dealing with financial shocks and that even though the monetary policy rule is more aggressive, the volatility in the interest rate is lower as well. When the economy is hit by a productivity shock the best policy for the monetary authority is to accommodate the improvement in the productivity as much as possible. This is in contrast to the case of a demand shock; macroprudential policy tool is unwarranted.

Gerali et al. (2010), unlike me and the rest of these authors, incorporate a banking sector into the DSGE model. They look at the effects of an expansionary technology shock, and a contractionary monetary policy shock. They find that macroeconomic shocks play a minor role in explaining the fall in output in 2008 in the Euro area, while the shocks to the banking sector explain a lot more. The most important result to be had from their study is that much is lost in excluding explicitly financial and credit shocks in DSGE models designed to analyse fluctuations in business cycles.

Iacoviello and Neri (2010) also consider the spillovers from the housing market to the wider economy. But they also try to find out what types of shocks are hitting the housing market, and how the dynamics of residential investment and housing prices are clarified by shocks and frictions in the market. The authors' model is to some extent similar to those above, but instead of a supply side with a manufacturing sector with final- and intermediate goods, they model sectoral heterogeneity with a housing and a nonhousing sector. This modelling approach yields an additional effect from an increase in house prices, other than the traditional effect on borrowing constraints; the relative profitability of producing new homes is increased. This addition to the model generates an additional feedback mechanism that propagates and amplifies the cycle. Another key feature to this model is that it incorporates the collateral effects and that these effects help generate a positive and persistent response of consumption following an increase in housing demand. Without this effect the authors state that the increase in demand for housing would generate an increase in housing investment and housing prices, but a fall in consumption. A monetary shock leads in this model to a drop in real house prices, due mainly to nominal stickiness, and that both the collateral effect and nominal rigidities amplify the response to consumption. A positive technology shock leads to a decline in housing prices due to a rise in investment coming from a fall in construction costs. The main results to note are that technology shocks and housing demand shocks each explain about a quarter of the cyclical volatility in the housing investment and housing prices, and that the spillovers to the rest of the economy are quite important, but that the effect is concentrated on consumption rather than business investment.

4.2 The New Keynesian Dynamic Stochastic General Equilibrium Model

I ended up using the model of Matteo Iacoviello (2005), "*House Prices, Borrowing Constraints, and Monetary Policy in the Business Cycle*" from the American Economic review. The model was found in the American Economic review, but the Dynare Code was taken from the Macro Model Database, Wieland (2009). There are several similarities to the Iacoviello and Neri (2010) as well. While the paper is overly simplistic and stylised, relative to several of the other papers I have considered, it still gets the message through. Note that the main goal regarding my thesis will not be discovering a brand new model as this is PhD material at this level, but mainly estimating and analysing the results of an old one with Norwegian data. Hence, I will shortly explain the model I use.

There are several ways in which economists in this field of research are able to generate borrowing and lending within a dynamic stochastic general equilibrium framework, and still be able to isolate the desired effects. In order to apply the financial accelerator approach to the data one has to identify the different sectors on beforehand and give them certain characteristics that are easy to model, and which are expected to yield reasonable results. Having a household sector that maximises utility with respect to consumption, holding of housing, labour and money balances subject to a budget constraint; one ads a microfoundation to a macroeconomic framework. I further make the assumption that households are either patient; following a permanent income hypothesis behavioural pattern, or impatient; following something similar to a Rule-of-Thumb consumption pattern. Incorporating ROT consumers has gained a hold in the literature lately. There will also be an entrepreneurial sector and a retail sector, of which is rather standard in these types of New Keynesian DSGE models. I further argue that the entrepreneurial sector and the impatient type of households are the key element in this model, due to the two sectors facing borrowing constraints. Hence, they borrow funds from intermediaries in accordance with their net worth, of which depends on the house prices in any given period. In addition to the households, the entrepreneurs and the retailers there will also be a central bank following a Taylor type rule.

4.2.1 Households

The households are infinitely lived, along with the entrepreneurs, and are further divided into a patient type and an impatient type. The impatient type is only separated from the patient ones through different discount rate; impatient households are assumed to have a higher discount rate. The impatient households are hence assumed to be more myopic and face borrowing constraints, indicating that they can in fact take advantage of MEW in the case of equity price increases, but no other way of borrowing is available for these types. The patient households maximize the following utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(lnc'_t + jlnh'_t - (L'_t)^{\frac{\eta}{\mathrm{N}}} + \chi \ln\left(\frac{\mathrm{M}'_t}{\mathrm{P}'_t}\right)\right)$$

subject to the budget constraint

$$c_t' + \ q_t \Delta h_t' + \frac{R_{t-1} b_{t-1}'}{\pi_t} = \ b_t' + \ w_t' L_t' + \ F_t + T_t' - \frac{\Delta M_t'}{P_t} - \ \xi_{h,t}$$

With respect to consumption c_t', holding of housing h_t', labour supply in hours L_t', and money balances divided by the price level is given by $\frac{M_t'}{P_t}$. The household sector is denoted with a prime and the impatient households are denoted with a double prime, just like in Iacoviello (2005).

The impatient household maximization problem is then, in a similar manner

$$E_0 \ \sum_{t=0}^{\infty} \ (\beta'')^t \ (lnc_t'' + jlnh_t'' - (L_t'')^{\frac{\eta}{\mathrm{N}}} + \chi \ln \left(\frac{\mathrm{M}_t''}{\mathrm{P}_t'{}'}\right))$$

Subject to the budget constraint

$$c_t'' + \ q_t \Delta h_t'' + \frac{R_{t-1} b_{t-1}''}{\pi_t} = \ b_t'' + \ w_t'' L_t'{}' + \ F_t + T_t'' - \frac{\Delta M_t''}{P_t} - \ \xi_{h,t}$$

$$b_t'' \leq \ m'' E_0 (\frac{q_{t+1} h_t'' \pi_{t+1}}{R_t})$$

Where $\xi_{h,t} = \frac{\phi_h \left(\frac{\Delta h_t''}{h_{t-1}''}\right)^2 q_t h_{t-1}''}{2}$ is the way we denote the housing adjustment cost, but it plays a minor role in my further analysis and can therefore be disregarded with ease.

E_0 is the expectations operator, $\beta \epsilon \ [0,1]$ is the discount factor, q is the real housing price (Gross price Q divided by price level P), w is the real wage (Gross wage W divided by price level P). I further assume that households borrow in real terms –b, and receive back $\frac{R_{t-1} B_{t-1}'}{P_t}$, where R_{t-1} is the nominal interest rate on loans between t-1 and t. Δ is the difference operator in the budget constraint, $\pi_t = \frac{P_t}{P_{t-1}}$ denotes the gross inflation rate, F denotes the lump sum transfers received from the retailers, T - ΔM/P denotes the net transfers from the central bank financed through printing new money. j is the weight one puts on housing services, also the demand shock, and η is the labour supply aversion.

The housing preference shock may be regarded as a shock that captures other social and institutional changes that shift housing preferences, or even cyclical deviations in the availability of resources needed to purchase housing, h, relative to other goods, c.

Maximizing the utility function, with respect to c, h, L and M/P, subject to the budget constraint, one arrives to the first order conditions. In a similar fashion to Iacoviello (2005) I will disregard the money demand. Since I use a separable utility function, ignoring the quantity of money will not have any consequences for the rest of the model.

4.2.2 Entrepreneurs

Using only labour, capital and real estate as inputs the entrepreneurs produce the intermediate good according to a constant returns-to-scale Cobb-Douglas production function:

$$Y_t = A_t K_{t-1}^{\mu} h_{t-1}^{\nu} L_t'^{\alpha(1-\mu-\nu)} L_t''^{(1-\alpha)(1-\mu-\nu)}$$

We further make the assumption that the entrepreneur, similar to a consumer, wishes to maximize consumption with respect to the borrowing constraint condition, technology, and the corresponding budget constraint.

$$Max\ \ E_0 \sum_{t=0}^{\infty} \gamma^t \ln c_t$$

$$subject\ to\ b_t\ \le mE_t\left(\frac{q_{t+1}h_t\pi_{t+1}}{R_t}\right)$$

$$Y_t = A_t K_{t-1}^{\mu} h_{t-1}^{\nu} L_t'^{\alpha(1-\mu-\nu)} L_t''^{(1-\alpha)(1-\mu-\nu)}$$

$$\frac{Y_t}{X_t} + b_t = c_t + q_t \Delta h_t + \frac{R_{t-1}b_{t-1}}{\pi_t} + w_t' L_t' + w_t'' L_t'' + I_t + \xi_{e,t}\xi_{K,t}$$

Where A is the random technology parameter, L' and L'' are the labour supply of the different types of households, α denotes the wage share of the unconstrained agents, and μ denotes the capital share in the economy. K is capital and δ is the depreciation rate. ξ denotes the adjustment costs for both the sectors, defined as in Iacoviello (2005). m is the loan-to-value ratio and will in most cases define how much one can borrow, with collateral. I further make the assumption that the entrepreneurial discount factor is lower than the patient household discount factor, but still as high as the impatient household discount factor. This implies for the model I use that the entrepreneurs and the impatient household are in fact bounded by the borrowing constraint around the steady state. $\beta''\ and\ \gamma < \beta$ in fact makes sure that entrepreneurs and borrowing constrained households decumulate wealth quick enough to a lower bound such that the borrowing constraint is binding. One complication with this model, as Iacoviello notes, is that we want to avoid that the entrepreneurs and the impatient households amass wealth and self-insure. In order to get the desired effects of collateral one needs that these ROT consumers hit the borrowing constraints. Iacoviello makes good arguments why the probability of this this may be small enough that I disregard this nuisance fact.

4.2.3 Retailers

As in most of the models we have covered in this paper, the retail sector is mostly brought along in order to introduce price rigidities and monopolistic competition into the model and to render the model linear. Price stickiness guarantees that monetary policy has real effects to the economy and is introduced through a Calvo-pricing regime. A Calvo price setting rule assumes that each firm resets its price only with probability 1-θ in any given period, no matter when it last reset its price. In other words, in each period a fraction 1-θ resets its price, while a fraction θ keep their prices unchanged. The average duration of a price then becomes $\frac{1}{1-\theta}$ and in this context θ is then considered a natural price index of price stickiness. Assuming a continuum of retailers and that they purchase intermediate goods from entrepreneurs and (inducing the fact that only the retail sector is characterised by monopolistic behaviour) differentiate the goods at no extra costs. Their production function, final goods, is given by:

$$Y_t^f = (\int_0^1 Y_t(z)^{\varepsilon - \frac{1}{\varepsilon}} dz)^{\frac{\varepsilon}{\varepsilon} - 1}$$

And the price index is then given by:

$$P_t = (\int_0^1 P_t(z)^{1-\varepsilon} dz)^{\frac{1}{1-\varepsilon}}$$

Each retailer faces then an individual demand curve derived to be:

$$Y_t(z) = \left(\frac{P_t(z)}{P_t}\right)^{-\varepsilon} Y_t^f$$

Adding just another equation to the retail sector one is then able to derive the maximisation problem, the price evolution is:

$$P_t = (\theta P_{t-1}^{\varepsilon} + (1-\theta)(P_t^*)^{1-\varepsilon})^{\frac{1}{1-\varepsilon}}$$

θ denotes the staggered price setting à la Calvo (1983). A fraction (1-θ) is allowed to re-optimise its price in any given period, given by P_t^*.

Firms chose output, prices and labour input in order to maximise expected profits subject to the individual demand curves, production technology function and the different Calvo-states. Setting up the Lagrangian and deriving the first order conditions with respect to prices, output and labour input and we get the following condition:

$$\sum_{k=0}^{\infty} \theta^k E_t \left(\Lambda_{t,k} \left(\frac{P_t^*(z)}{P_{t+k}} - \frac{X}{X_{t+k}} \right) Y_{t+k}^*(z) \right) = 0$$

Where $\Lambda_{t,k} = \beta^j \left(\frac{c_t'}{c_{t+k}'} \right)$ is the relevant discount, and $X = \frac{\varepsilon}{\varepsilon - 1}$ is the markup of final goods over intermediate goods in steady state. Assuming zero inflation in steady state and log-linearizing we get the New Keynesian forward looking Phillips Curve (NKPC). The forward looking Phillips Curve postulates that inflation depends positively on expected inflation and negatively on the markup.

4.2.4 The central bank

The central bank in this model is assumed to follow a backward looking interest rate rule, according to a Taylor principle. The Taylor principle states that the central bank reacts to inflation shock more than one-to-one in order to affect the real interest rate.

$$R_t = (R_{t-1})^{rR} (\pi_{t-1}^{1+r\pi} \left(\frac{Y_{t-1}}{Y} \right)^{rY} rr)^{1-rR} e_{R,t}$$

Where I denote rr and Y as steady state values of real rate and output, just as in Iacoviello (2005). $e_{R,t}$ is the inflation shock, or white noise shock process that is identically and independently distributed with variance σ_e^2 and zero mean.

4.2.5 Equilibrium

The first order conditions obtained from the households' maximisation problem, firm maximisation problem, as well as the central bank interest rate rule, make up the DSGE model in a stylised manner. The equilibrium model is derived using market clearing conditions in the housing market, labour market, real estate, goods market and market for loans. Log-linearizing the complete model around a steady state in order to reduce the computational difficulty for the system of equations that need to be solved simultaneously is a frequently used method in DSGE macro models. This method of transforming non-linear equations into linear in terms of log-deviation of the related variables from their steady state values is intensely used in macroeconomics, as well as microeconomics. For small enough deviations from steady state we interpret the log-deviations as percentage deviations from steady state, hence the “hat” in the following model. The complete log-linearized model is as follows, taken directly from Iacoviello (2005), Appendix A page 760-761:

Aggregate demand

$$Yhat_t = \frac{c}{Y} chat_t + \frac{c'}{Y} c'hat_t + \frac{c''}{Y} c''hat_t + \frac{I}{Y} Ihat_t$$

$$c'hat_t = c'hat_{t+1} - rrhat_t$$

$$\begin{aligned} Ihat_t - Khat_{t-1} \\ &= \gamma(Ihat_{t+1} - Khat_t) + \frac{1-\gamma(1-\delta)}{\psi}(Yhat_{t+1} - Xhat_{t+1} - Khat_t) \\ &+ \frac{1}{\psi}(chat_t - chat_{t+1}) \end{aligned}$$

The first equation is the clearing condition in the goods market, while the second equation is the first order condition (FOC) for the patient households. The last equation defines the investment.

Housing/consumption margin

$$\begin{aligned} qhat_t = \gamma_e qhat_{t+1} + (1-\gamma_e)(Yhat_{t+1} - Xhat_{t+1} - hhat_t) - m\beta rrhat_t \\ - (1-m\beta)\Delta chat_{t+1} - \phi_e(\Delta hhat_t - \gamma \Delta hhat_{t+1}) \end{aligned}$$

$$\begin{aligned} qhat_t = \gamma_h qhat_{t+1} + (1-\gamma_h)\left(jhat_t - h''hat_t\right) - m''\beta rrhat_t + (1-m''\beta)(c''hat_t \\ - \omega c''hat_{t+1}) - \phi_h(\Delta h''hat_t - \beta'' \Delta h''hat_{t+1}) \end{aligned}$$

$$\begin{aligned} qhat_t = \beta qhat_{t+1} + (1-\beta) jhat_t + \iota hhat_t + \iota'' h''hat_t + c'hat_t - \beta c'hat_{t+1} \\ + \frac{\phi_h}{h'}\left(h\Delta hhat_t + h''\Delta h''hat_t - \beta h \Delta hhat_{t+1} - \beta h'' \Delta h''hat_{t+1}\right) \end{aligned}$$

The first equation here denotes the optimal condition for entrepreneurs, the second the optimality condition for impatient household and the last one the non-myopic households demand.

Borrowing constraints for the firm and the households

$$bhat_t = qhat_{t+1} + hhat_t - rrhat_t \qquad b''hat_t = qhat_{t+1} + h''hat_t - rrhat_t$$

Aggregate supply

$$Yhat_t = \frac{\eta}{\eta - (1 - \nu - \mu)}(Ahat_t + \nu hhat_{t-1} + \mu Khat_{t-1}) - \frac{1 - \nu - \mu}{(\eta - (1 - \nu - \mu)}(Xhat_t + \alpha c'hat_t + (1 - \alpha)c''hat_t)$$

$$\pi hat_t = \beta \pi hat_{t+1} - \kappa Xhat_t + uhat_t$$

Here we have the log-linearized production function with the market clearing condition already incorporated, together with the Phillips curve.

Budget constraint and capital evolution process

$$Khat_t = \delta Ihat_t + (1 - \delta)Khat_{t-1}$$

$$\frac{b}{Y}bhat_t = \frac{c}{Y}chat_t + \frac{qh}{Y}\Delta hhat_t + \frac{I}{Y}Ihat_t + \frac{Rb}{Y}(Rhat_{t-1} + bhat_{t-1} - \pi hat_t) - (1 - s' - s'')(Yhat_t - Xhat_t)$$

$$\frac{b''}{Y}b''hat_t = \frac{c''}{Y}c''hat_t + \frac{qh''}{Y}\Delta h''hat_t + \frac{Rb''}{Y}(b''hat_{t-1} + Rhat_{t-1} - \pi hat_t) - s''(Yhat_t - Xhat_t)$$

In the first equation here we clearly see how the capital evolves over time, the Law of motion equation for capital, along with the forces at work regarding the net worth of both firms and households.

Monetary policy rule and stochastic AR(1) processes

$$Rhat_t = (1 - r_R)(1 + r_\pi)\pi hat_{t-1} + r_Y(1 - r_R)Yhat_{t-1} + r_R Rhat_{t-1} + ehat_{R,t}$$

$$jhat_t = \rho_j jhat_{t-1} + ehat_{j,t}$$

$$uhat_t = \rho_u uhat_{t-1} + ehat_{u,t}$$

$$Ahat_t = \rho_A Ahat_{t-1} + ehat_{A,t}$$

The first stochastic Ar(1) process denotes the demand shock, (or preference shock), the second on denotes the cost-push shock and the last one the technology shock, (or supply shock).

Where $rrhat \equiv Rhat_t - E_t \pi hat_{t+1}$ is the real ex ante interest rate. $\iota = \frac{(1-\beta)h}{h'}$, $\iota'' = \frac{(1-\beta)h''}{h'}$, $\gamma_h \equiv \beta'' + m''(\beta - \beta'')$, $\kappa = \frac{(1-\theta)(1-\beta\theta)}{\theta}$ and $\omega = \frac{\beta'' - m''\beta''}{1-m''\beta}$ and noticing that $s' \equiv \frac{\alpha(1-\mu-\nu)+X-1}{X}$ and $s'' \equiv \frac{(1-\alpha)(1-\mu-\nu)}{X}$ in the log-linearized equation, where they denote the income share of the patient and impatient households, respectively. Iacoviello (2005) defines $\gamma_e \equiv (1-m)\gamma + m\beta$ as the average discount factor for the returns to entrepreneurial real estate investment.

5 Quantitative Policy Analyses and Estimation

5.1 Methodology and data

I will use a Bayesian New Keynesian Synthesis (NNS) estimation approach and choose both calibrated parameters and appropriate prior distributions for the parameters that I estimate.

"Bayesian NNS models, therefore, combine a sound, microfounded structure suitable for policy analysis with a good probalistic description of the observed data and good forecasting performance" Smets and Wouters (2007) pp. 587

The likelihood function is assessed using a Kalman filter. The posterior distributions are then done using a Metropolis Hastings algorithm, within the free software Dynare4.2.0 along with Matlab version R2010b, to draw the posterior distribution of the parameters. I estimate the model using four observable variables; GDP in fixed prices, CPI adjusted for taxes and energy prices (hereafter CPI-ATE), nominal house prices deflated by the CPI-ATE and the 3 Month NIBOR for the period 1995Q1 – 2010Q4. For the period I wish to examine I have come to the conclusion that GDP and real house prices will most likely have a trend, inflation and NIBOR are assumed to be without a trend and are therefore not filtered. They are, nonetheless, demeaned. Hence, both real GDP and real house prices have been detrended using a Hodrick-Prescott filter (HP) after first having been recalculated to log values. More on this in the Appendix.

After doing this I intend to go on to do some comparative analysis through showing the impulse responses to different shocks to real GDP, nominal interest rates, real house prices, inflation and consumption. Using the baseline model as a benchmark I will then plot the impulse responses with no collateral effects for constrained households (m = m''= 0). Doing so, I can estimate the spillovers from the housing market to consumption. I intend to measure the spillovers to the general economy through the notion that the conventional wealth effect on consumption is greater when collateral effects are indeed present. Also, another large part of the spillovers come from the notion of the wage share of the constrained households. These are the financial frictions mentioned in the beginning of my thesis. I will also check what would happen if the central bank, in addition to reacting to last period nominal interest rates, activity in the economy and last period inflation, keep an eye on current asset prices as well. The reason is that asset prices that are let to overinflate will have large repercussions for the economy. In this manner, one can check whether it would be beneficial for a central bank to implementing asset prices into the monetary policy rule. The limited gains of asset prices in the policy specification are already noted in the literature. I will elaborate on this on a later.

5.2 Calibrated parameters

One important reason why we often calibrate certain parameters is that some parameters are known to be hard to pin-point and therefore hard to estimate, or that other papers have already identified the relevant value of the parameters in question. Calibration necessitates that the values of the parameters are collected from other sources independent of the phenomenon under study.

"*This controversial step is driven by three main concerns. First, identification of deep parameters in estimated large dynamic systems can be troublesome. Second, there is often a conceptual mismatch between the theoretical variables and their sample counterparts. ...And third, in practice the classical estimation of macro models can be plagued by badly-behaved likelihoods – the researcher typically has very few business cycle fluctuations with which to estimate the highly abstract model*." Karagedikli et al. (2008) pp. 10

The parameters that I chose to calibrate for the Norwegian data are also the ones that are most commonly calibrated, such as the discount rate for the different types of households, capital share and wage share of the economy, depreciation rate of capital and mark-up of final- over intermediate goods and LTV ratios.

Table 1 – Parameter calibration

Parameter	Description	Value
β	Discount factor for patient household	0.9994
β''	Discount factor for impatient household	0.97
γ	Discount factor for entrepreneurial sector	0.97
m''	Loan-to-value ratio for households	0.8
m	Loan-to-value ratio for entrepreneurs	0.35
j	Weight on housing services	0.2
η	Labour supply aversion	1.01
ν	Housing share	0.03
Ψ	Variable capital adjustment cost	2
δ	Variable capital depreciation rate	0.0180
φ_e	Housing adjustment cost, entrepreneurs	0
φ_h	Housing adjustment cost, impatient HH	0

The parameters that I have calibrated are given on Table 2, with their corresponding value. Most of the time these calibrated values will be close to or taken directly from US or European studies on the literature. I have, nonetheless, also used Norwegian studies where this was possible. I further make the assumption that using estimates from literature on the subject based on American or European studies will not have significant impact on my estimation procedure and my estimation results. I calibrate β to be 0.9994 based on a Norwegian study by Bache et al. (2010), implying an annual steady state real return on financial assets of about 0.25%. This seems rather intuitive since Norwegian consumers have a higher savings ratio than their American counterparts in Iacoviello`s study. The impatient households discount factor, β'', is calibrated to 0.97 just as in Iacoviello and Neri (2010) and this will enable the ROT consumers to hit the borrowing constraints. Iacoviello (2005) sets γ to be 0.97 as it proxies for the internal rate of return for the firms. Considering that Norwegian firms have higher wage costs and lower productivity than their American counterparts, I have reason to believe this to be different from the one Iacoviello uses. In a working paper estimating a DSGE model for the Euro area with a data set from ECB, Gerali et al. (2010) calibrate this value to 0.97, similar to the impatient households discount factor. Lacking Norwegian estimates on the subject I will, nevertheless, stick with these authors choice here as well. The LTV parameter is calibrated to be 0.8 for Norway based on a cross country study by Tasatsaronis and Zhu (2004). I calibrate the entrepreneurial LTV ratio to 0.35, following Gerali et al. (2010). This implies that non-residential property is more easily collaterisable than residential property. I believe this parameter does not differ a lot from Norway and, hence, will calibrate the same value for the LTV. These calibrated values of the LTV ratios are meant to measure the typical credit constrained borrowers LTV ratios and define the maximum possible amount they can borrow against their home/collateral. The weight on the housing services is set to 0.2 as in Gerali et al. (2010); Norwegian consumers are by assumption putting no more weight on housing services than their European counterparts. δ is calibrated to 0.0180 in accordance with the capital depreciation rate for Norwegian data in Bache et al. (2009), implying a quarterly depreciation rate of capital of 1.8%.

η, ψ, φ and ν are the parameters that I will be following Iacoviello (2005) on as well and calibrate them to 1.01, 2, 0 and 0.03, respectively. This is due to the complication of estimating these parameters in my relatively stylised model.

5.3 Bayesian estimation

In the Bayesian framework the parameters are considered random variables and hence the objective is to make conditional probalistic statements about the parameters. Conditional on the structure of the model, observed data and the prior distribution specified for the parameters. The first two are then used to form a likelihood function; the result is then, along with the prior distribution, used to get the associated posterior distribution using Bayes` Rule.

In these types of models, New Keynesian DSGE-models, one often ends up estimating key parameters using prior information, which is a clever way of avoiding the calibration problems number one and three from above. Here the priors will act as a catch-all for information that is not in the sample data. One might even argue that the calibration method is an extreme variant of Bayesian procedure since we focus on one single value of the parameter. Using such a strong prior, the observations of the data series add nothing to our knowledge of the parameter values and the posterior density overlaps with the prior one.

"*While, in principle, priors can be gleaned from personal introspection to reflect strongly held beliefs about the validity of economic theories, in practice most priors are chosen based on some observations*." An and Schorfheide (2007) pp. 127

The main advantages of using priors; using all the relevant information from past studies and estimations makes sense since it makes the model and estimation more robust than it would have been for a single sample, and it makes sure that less new testing is needed to confirm confidence intervals when priors are encouraging. There are of course drawbacks to using priors; prior information may in some cases not be accurate and this will lead to misleading conclusions and results; for example if priors are from models with different characteristics and cannot be compared as such, and the results are not in any way objective since they represent the researchers subjective opinion on the choice of prior. The priors express the researcher's opinion about the likely value of the parameter in question. And by using Bayes formula one derives the posterior probability of the value of the parameter, revising the starting assessment. One might say that the posterior density summarises what we know about a parameter after observing the data. And since we are considering structural parameters, it is also the basis for probalistic statements about them. In Dynare this is done using Kalman Filter to find numerical values that maximise the prior and the sum of the likelihood. It is, nonetheless, important to notice that the posterior of one parameter is dependent of the priors of all the other parameters; changing one prior will change the rest of the estimated posterior distributions as well. Specifying a prior necessitates a lot of other information, and it may as such be difficult doing so. This is because one does not only specify the mean value of the parameter one expects the parameter to have, but also the distribution of the prior and the standard deviation. Avoiding the headache that is choosing a prior and prior distribution one can use un-informative priors, using rather vague information, but this is to say that one misrepresents one`s knowledge about a parameter.

Following the convention of recent papers estimating similar DSGE models using prior information; I will use the inverse gamma distribution for parameter values that need to be constrained by the zero lower bound and are relatively small in value (mostly reserved for the distribution of the standard deviation of the shocks), beta distribution for parameters that are restricted between zero and one, gamma distribution for parameters restricted to be positive, normal distribution for values of other dimensions.

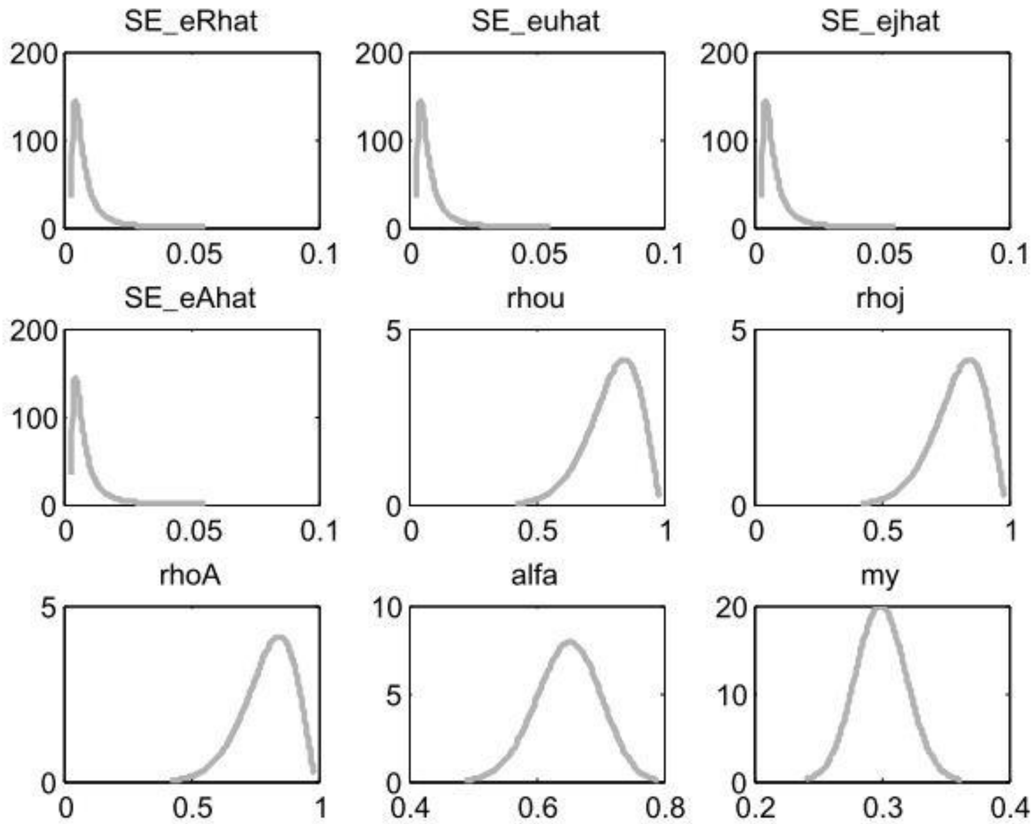


Figure 12 – Prior distributions of some of the parameters.

5.3.1 Prior distribution

The priors I have chosen for the estimation are given in table 3. These are overall in the same range as previous studies. As for the monetary policy specification, I chose priors conveying different weight on inflation deviations, (output deviations) and interest rate according to a Taylor rule. I have assumed prior means, based on the posteriors of a Norwegian DSGE study, Bache et al. (2010), prior means for the policy weight parameters of 0.67, 1.5 and 0.45 were used for $r_R,\ r_\pi\ and\ r_Y$, respectively. These are almost identical to the Gerali et al. study on European soil. Note, however, that Bache et al. (2010) consider an open economy, and also incorporate exchange rate. The patient household wage share prior mean is set to 0.65 with a standard error of 0.05, as in Iacoviello and Neri (2010). Bache et al. (2010) calibrate capital share to be 0.3, I chose their value as prior mean along with a standard error of 0.02. θ, the staggered price setting parameter is set 0.75 with a beta distribution, implying that retailers re-optimise their price every 4 quarters. Choosing this value from a US study, I believe, will not stultify the posterior distribution of the parameter. The steady state mark-up is set to be 5% in Iacoviello (2005) and a 15% mark-up is assumed in Iacoviello and Neri (2010), I have, nevertheless, reason to believe there to be a lesser degree of competition in Norway, so this might just be higher for Norwegian data. Setting it to be in the ballpark of these estimates, I set prior mean of the mark-up, X, to 1.20. Prior mean of 0.8 has been chosen for the AR (1) coefficients with a standard error 0.1, implying a great degree of persistence in the shocks, following Iacoviello and Neri (2010). The standard deviations of the shocks are set to 0.01 with a standard deviation of 0.05 as in the model of Gerali et al. (2010).

5.3.2 Posterior distribution

Now that I have used frequently calibrated parameters and estimated other parameters such as patient household wage share, capital share, Calvo parameter and monetary policy parameters, using Bayesian estimation, I will go on to discuss whether my estimation results are reasonable prima facie. The posteriors are estimated with 20 000 Metropolis Hastings draws, yielding an almost ideal acception rate of 0.248 (25% being ideal).

Table 3 also displays the posterior mean and the 95% probability intervals for the parameters. I find a wage share of about 0.73 for unconstrained agents for the Norwegian economy, implying that the constrained agents wage share is about 0.27. Overall this is above the prior mean that is set to 0.65. If this value is large enough that it yields the desired results that the elasticity of consumption with respect to house prices for constrained agents is positive and large enough stands to see. Capitals share in the Cobb-Douglas production function is estimated to 0.31 which is satisfyingly close to the prior mean. This means that the labour income share in this model of Norwegian economy is about 69%. My estimate for the staggered price setting parameter implies that firms re-optimise their price on average almost every year. The mark-up of final goods over intermediate goods is estimated to 1.21, which says that the estimated mark-up is about 21%. As for the policy parameters, the importance assigned to output deviation, inflation deviation and interest rate smoothing are what should be expected for an inflation targeting central bank. These estimates imply that the central bank allots a lot of importance towards keeping inflation stable, although less than prior mean suggests. Relatively less importance is assigned to output stabilisation, while interest rate smoothing is assigned more stressed than the interest rate smoothing coefficient imply. Bache et al. (2010) estimated these parameters to 1.5, 0.67 and 0.45, respectively. We see that my estimates, although not directly comparable since we use different models (open versus closed economy) and different data, are somewhat close to their estimates. Their estimates suggest that the central bank stresses inflation deviations more than my estimates would imply. They also find that less importance is assigned to interest rate smoothing and output stabilisation than my estimates suggest. This is in line with the inflation targeting regime that the Norwegian central bank accords to, as one of few central banks with an explicit inflation target. This explicit inflation target Norges bank adheres to is set at 2.5% over time. The AR(1) persistence parameters are quite high, implying a high degree of pass-through to the next period. The autoregressive demand shock coefficient is estimated to almost 0.95, indicating a great degree of persistence. The cost-push shock is estimated to almost unity, meaning an almost complete pass-through of the shock to the next period. In other words, these shocks are extremely persistent. The technology shock AR(1) persistence parameter is estimated to about 0.75, implying that about three quarter of the shock is passed over to the next period. These are not in contradiction to the ones Gerali et al. (2010) estimate for European data, Iacoviello and Neri (2010) estimates on US data, and also around the prior means of Bache et al. (2009) on Norwegian data. The standard deviations of the shock are reasonably low, as is also the case in Iacoviello (2010) paper.

Table 2 - Prior and Posterior distribution of the parameters

Description	Parameter	Prior distribution	Prior mean	Prior se.	Posterior mean	95% Confidence interval
Factor shares, LTV ratios and other deep parameters						
Unconstrained agents wage share	α	Beta	0.65	0.05	0.7318	0.67 – 0.80
Variable capital share	μ	Beta	0.3	0.02	0.3086	0.27 – 0.34
Calvo-parameter	θ	Beta	0.75	0.05	0.7500	0.66 – 0.83
Mark-up	χ	Gamma	1.2	0.1	1.2096	1.04 – 1.36
Interest rate smoothing – CB`s own lag	r_R	Beta	0.67	0.1	0.9129	0.89 – 0.93
Output deviations	r_Y	Gamma	0.45	0.1	0.6315	0.51 – 0.75
Inflation deviation	r_π	Gamma	1.5	0.1	1.3603	1.21 – 1.50
Reaction to asset prices***	r_q	Normal	0.15	0.1	0.0338	0.00 – 0.07
AR(1) coefficients						
Cost-push	ρ_u	Beta	0.8	0.1	0.9769	0.96 – 0.99
Demand	ρ_j	Beta	0.8	0.1	0.9491	0.92 – 0.98
Supply /tech. shock	ρ_A	Beta	0.8	0.1	0.7500	0.69 – 0.81
St.d. of shocks						
Cost-push	σ_u	Inv. gamma	0.01	0.05	0.0019	0.0015 – 0.0023
Demand	σ_j	Inv. gamma	0.01	0.05	0.5817	0.43 – 0.72
Supply –tech. shock	σ_A	Inv. gamma	0.01	0.05	0.0457	0.04 – 0.05
Interest rate shock	σ_R	Inv. gamma	0.01	0.05	0.0018	0.0016 – 0.0021

*** Was estimated separately as the rest of the estimates above. Prior means for the policy weight parameters of 0.67, 1.5 0.45 and 0.15 were used for r_R, r_π, r_Y *and* r_q, respectively.

The following graph depicts my prior density (grey curve), the estimated posterior density (black curve), and the green vertical line depicts the posterior value for the different parameters. As we see from the graph the distributions of the prior differ at times from the posterior estimates, but overall the prior distribution coincides with the posterior distribution.

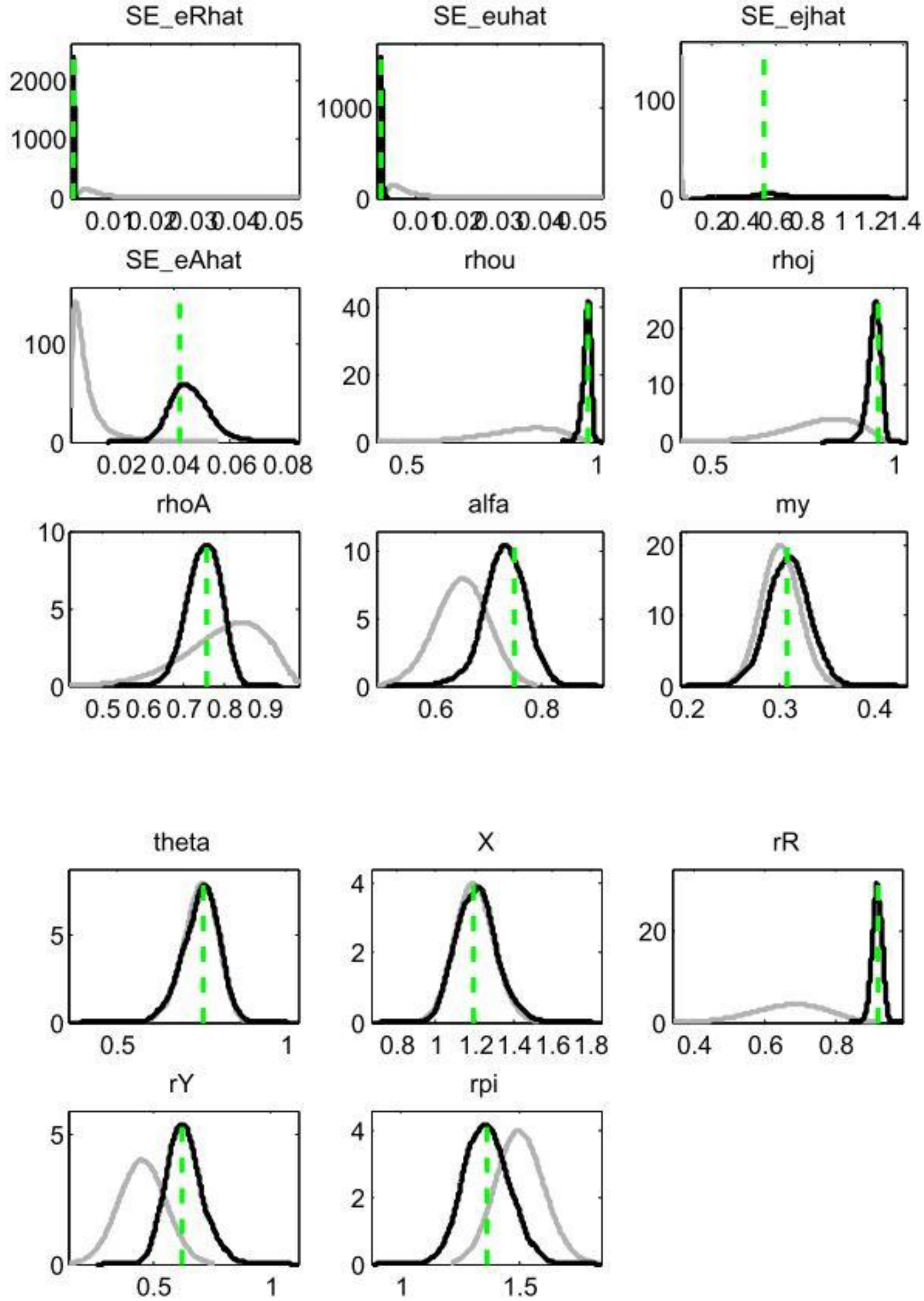


Figure 13 – Posterior distribution along with prior distribution. Black line depicts posterior distributions, grey depicts prior distributions and green depicts the posterior mean.

5.4 Properties of the estimated DSGE model

Table 3 - Correlation matrix of the simulated variables

Variable	Yhat	Rhat	qhat	pihat	chat	c''hat
Yhat	1.0000	-0.9919	0.9609	-0.8725	0.9791	0.8695
Rhat	-0.9919	1.0000	-0.9661	0.9241	-0.9818	-0.8114
qhat	0.9609	-0.9661	1.0000	-0.8506	0.9180	0.7323
pihat	-0.8725	0.9241	-0.8506	1.0000	-0.8993	-0.6158
chat	0.9791	-0.9818	0.9180	-0.8993	1.0000	0.8259
c''hat	0.8695	-0.8114	0.7323	-0.6158	0.8259	1.0000

The correlation matrix of the simulated variables indicates that there is a large positive correlation between the consumption of the entrepreneurial sector (chat) and house prices of 0.92, as well as a positive correlation between constrained household consumption (c2hat) and residential prices of the magnitude 0.73. I also find that real house prices are almost positively correlated with real GDP, but a strong negative correlation between real house prices and inflation rate. These results are similar to the ones obtained by Ahearne et al. (2005), although they find that real house prices are co-moving with inflation as well. Also, when assigning m'' and m a value of 0, i.e. no collateral constraint, we see that the correlation between real house prices and impatient household consumption is increased to 0.89, implying a larger correlation between them. For the entrepreneurial consumption, this correlation is slightly reduced. The correlation matrix to this simulated scenario is given in the Appendix C.

In the following graphs, figure 14 and 15, depicting smoothed variables, we see how the data portrays the quarter to quarter changes. We see that the house prices move strongly with output and that it lags the cycle slightly. When GDP is above trend then so are the real house prices. Real house prices are on the other hand a lot more volatile than the real GDP. Norway experienced a great economic boom in the period of 2003-2007. The low interest rates made sure that people were able and could afford to buy new houses or upgrade to a better one, leading to increased demand and, since supply is very inelastic in the short to medium run, increased house prices. After about 50 quarters we see that real house prices start their strong descent and drop to more than 0.08% below trend. This fall may largely be explained by the gradual increase in the policy rate from 1.75 in mid 2005 to 5.75 in the fall of 2008 along with increased scepticism regarding future prospects.

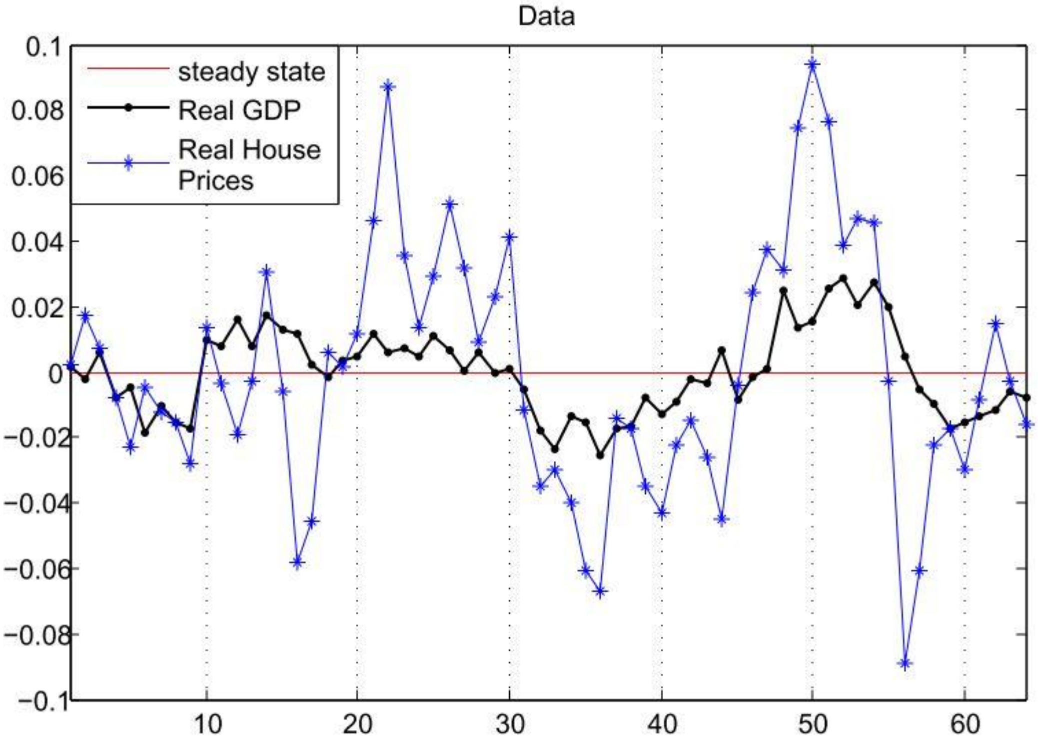


Figure 14 – Percentage deviations from steady state for the period 1995Q1 – 2010Q4.

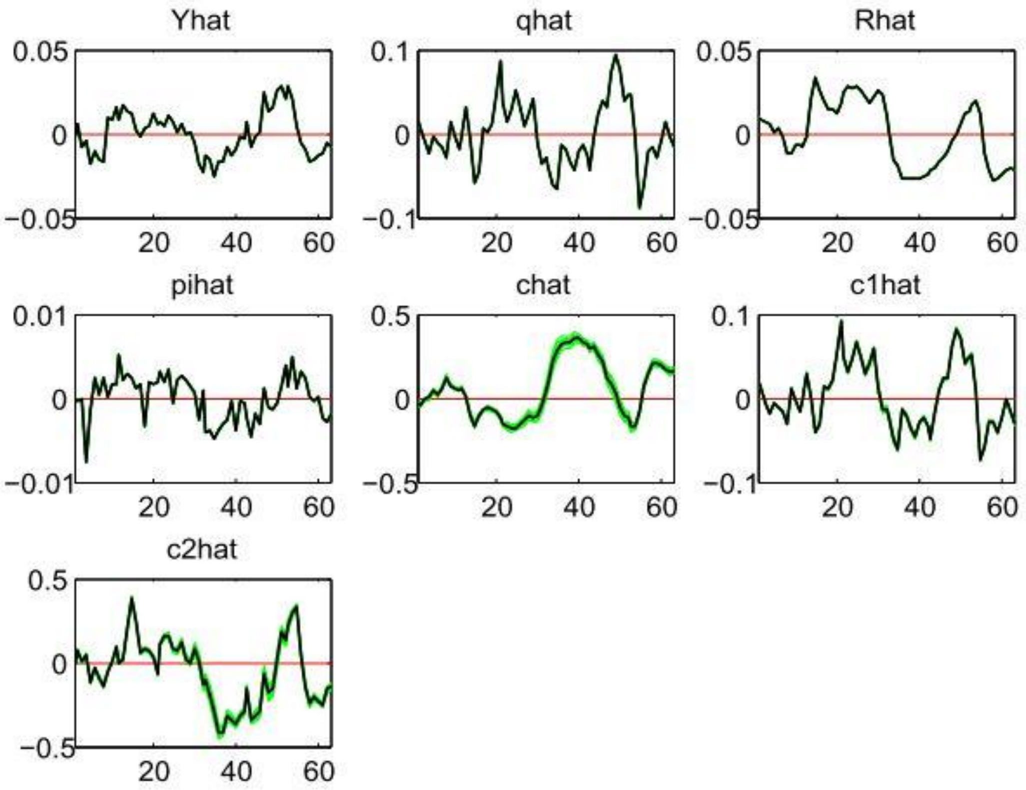


Figure 15 – Fluctuations around trend shown in the data for 1995Q1-2010Q4. Real GDP and real house prices have been detrended and are in their log-values. CPI is normalised to its 1999 value and demeaned. Nominal interest is also demeaned.

The impulse response functions of the estimated model are next on the list. I show the impulse responses of a contractionary monetary policy shock, a positive demand shock, a positive supply shock (technology shock) and an inflation surprise (cost-push shock). I also introduce a second curve in the same graphs incorporating a no-collateral constraint (m=m''=0). The reason why I do this is because one easy, and perhaps simplistic way, of showing the spillovers of house prices to consumption is to show the reinforced effects when there are collateral effects present. Increased house prices should therefore in my model lead to more consumption when households are able to withdraw more equity from their home, up to a LTV ratio of unity. This effect is perhaps strongest when considering monetary policy shocks. The credit channel effect of house prices on consumption is present only when we consider monetary and real shocks to the economy. The monetary policy shock is therefore my main concern; although I will, briefly, explain the other impulse responses as well. The impulse responses for 20 quarters are simulated using estimated parameters and calibrated parameters, yielding the following results:

Monetary shock. – A contractionary monetary policy shock to the economy, shown as the initial increase in nominal interest rate, leads initially to a fall in real GDP.

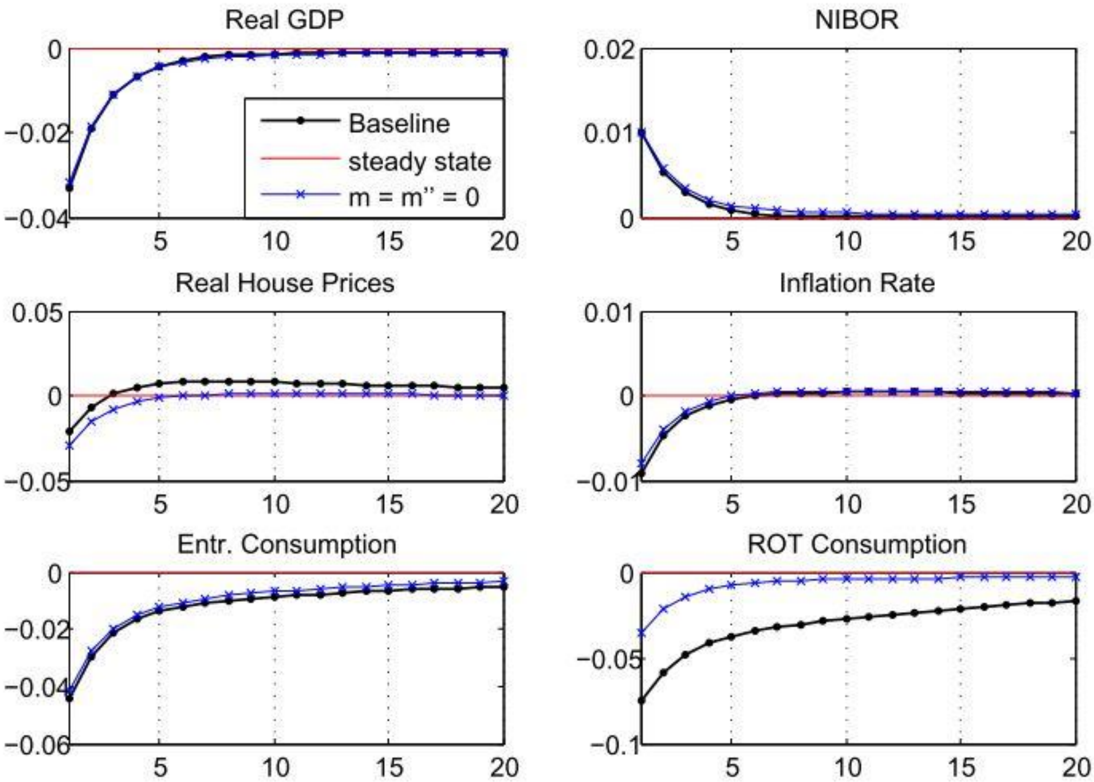


Figure 16 – Impulse responses to an iid. monetary policy shock.

Real GDP declines due to the shock, but moves towards the steady state within 5 quarters. The situation is quite similar when there are no collateral effects. Real house prices initially drop and hence worsen the cycle, as is reasonable due to fewer agents wishing to buy homes when the cost of financing increases, but it then overshoots the steady state after the economic recovery. In the no collateral effects case, real house prices display a bigger initial drop and it stabilises after around 5 quarters. The drop in real house prices is quite intuitive since asset prices generally decrease when interest rates increase. Overall on consumption, we see that the constrained households' reaction to the policy shock shows a smaller initial drop in consumption, compared to the case when collateral effects are present. The effects are as follows: Increased interest rates reduce asset prices and affect the borrowing constraints negatively. Increased LTV ratio and the effect on the borrowing constraint lead to lower borrowing opportunities for these households. We clearly see an amplification mechanism in the case of a negative monetary shock.

Housing preference shock. – A positive nominal demand shock to the economy is shown as a small initial drop in GDP in both scenarios. Normally a demand shock leads to an increase in activity, in my model; however, I have the opposite effect, although it is rather small. This is the same result as Iacoviello (2005) finds for US data.

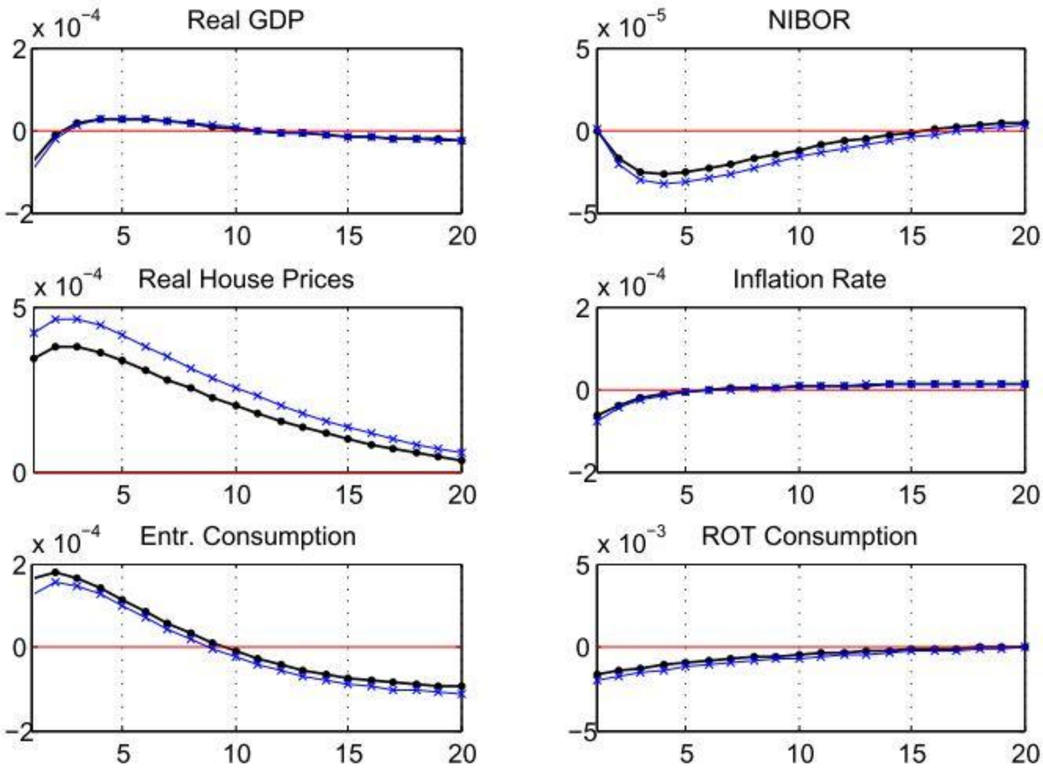


Figure 17 – Impulse responses to preference shock. Black curve is the baseline model, blue curve depicts when LTV ratios are set to 0.

A housing preference shock leads to a negative, albeit small, response of aggregate demand. From above we remember that a housing preference shock may also be regarded as a measurement of cyclical deviations of the availability of resources needed to purchase housing and institutional changes that affect housing demand. This is not directly comparable to a demand shock to output in different models, hence output falls and real house prices increase initially. Inflation falls initially, leading the central bank to react by reducing the policy rate. The lower policy rates lead to increased demand and consumption, as is shown in the graph. Real house prices increase initially and move towards the steady state after a while, displaying a hump-shaped pattern. In the case of no collateral effects, the effect is greater on house prices and marginally greater on consumption. Most of the time the two scenarios co-align with each other and there is no clear financial accelerator effect in play here.

Technology shock. – The positive technology shock to the economy has real effects, as we see on the real GDP. Real GDP displays a positive hump-shaped pattern after a couple quarters in both of the scenarios. Unlike the case of a demand shock, a supply shock generates a trade-off for the central bank.

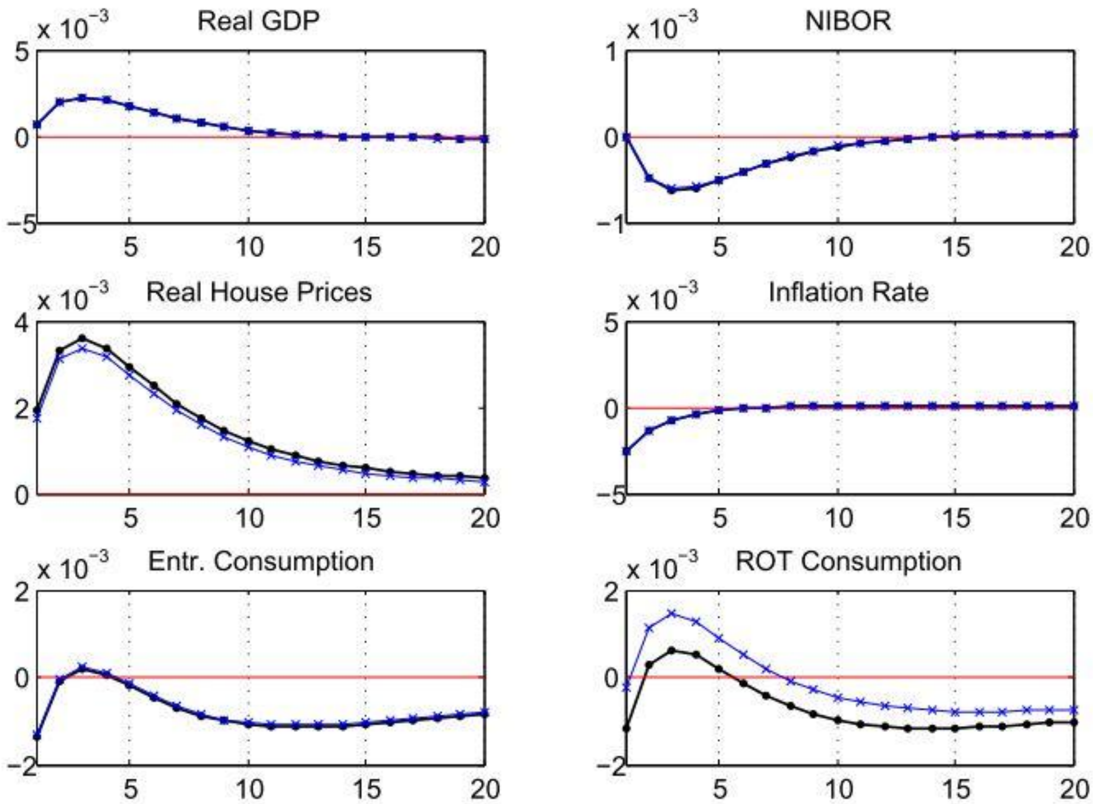


Figure 18 – Impulse responses to a positive technology (supply) shock. Black curve is the baseline model, blue curve depicts when LTV ratios are set to 0.

The positive technology shock leads to increased activity in the economy as well as deflation. Notice that the favourable technology shock is partly accommodated by the central bank, as the interest rate is decreased. The nominal interest rate should increase in order to dampen the supply shock on GDP, but it should decrease in order to increase inflation. We see, however, that it is reduced and should, according to a Taylor rule, imply that the policy rate is reduced more than the inflation in order to reduce the real interest rate. This is because the central bank is by assumption not frantically concerned with small output deviations. Instead we see that as the inflation rate starts its climb back towards steady state, the central bank increases the interest rate accordingly. The consumption of the constrained households displays a greater negative effect when there are collateral effects in play. This is in contrast to a monetary shock, as shown above. And as is already noted in Iacoviello (2005) for US data, I find for Norwegian data that a technology shock decelerates the economy.

Cost-push shock. – An inflation surprise is captured by the positive initial effect on real GDP, house prices, and as expected, a positive effect on inflation as well. The inflation pressure in the economy leads to a monetary tightening. As noted above, Tsatsaronis and Zhu found that inflation is the main driver of house prices. Since households are assumed to hedge against rising inflation with housing and due to inflation being regarded as a proxy for financial condition, we clearly see that rising inflation leads to reduced real house prices, in a hump-shaped pattern. The authors also argued that in the short run almost 90% of the variation in house prices may be due to inflation. There is a good reason why they are correlated indeed, seeing that a form of house prices/renting prices is incorporated in the CPI. The impulse response functions clearly show this effect in play. The collateral case here almost aligns with the no-collateral constraint scenario, except housing prices and consumption. We also see a clear difference between the collateral and the no-collateral effect case. Collateral effects lead to increased effect on consumption, displaying the spillovers of increased house prices.

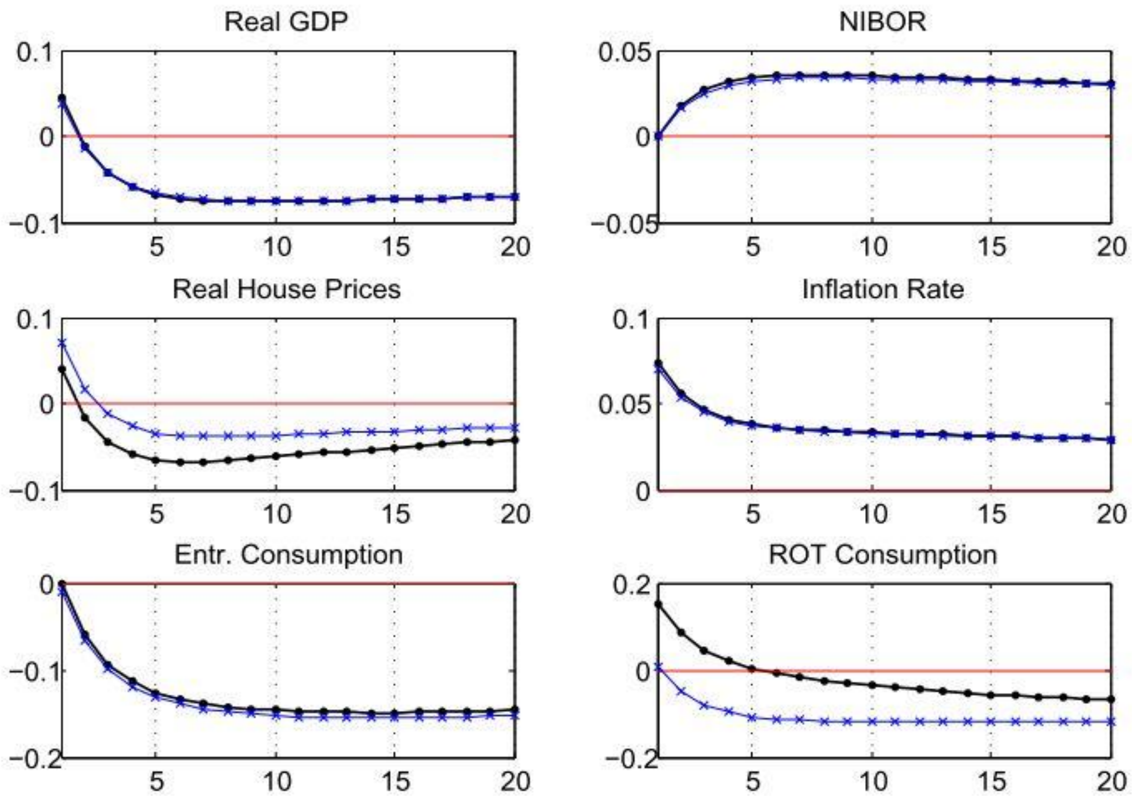


Figure 19 – Impulse responses to cost-push shock. Black curve is the baseline model, blue curve depicts when LTV ratios are set to 0.

Higher wage share of the constrained individuals –As explained above, the fraction of constrained to unconstrained agents in the economy matters a lot. Increasing the fraction of ROT consumers should, in theory, lead to increased effect of monetary policy shocks on asset prices, and therefore on consumption. The intuition is as follows: an unanticipated negative monetary shock to the economy leads to increased house prices → improving the financial position for the consumer → reduced LTV ratio → increased borrowing on the face value of the home → increase in consumption. Developments that increase the fraction of constrained to unconstrained households should therefore amplify this effect. ROT consumers are by definition consuming their entire income every period, they should in theory react more strongly to changes in house prices than their more patient counterparts. Reducing the wage share of the unconstrained agents, decreasing α, should proxy for more ROT consumers as well as a case of restricting the ease of credit unrelated to housing. I reduce α from 0.73 to 0.2 and analyse the impulse responses to a negative monetary policy shock.

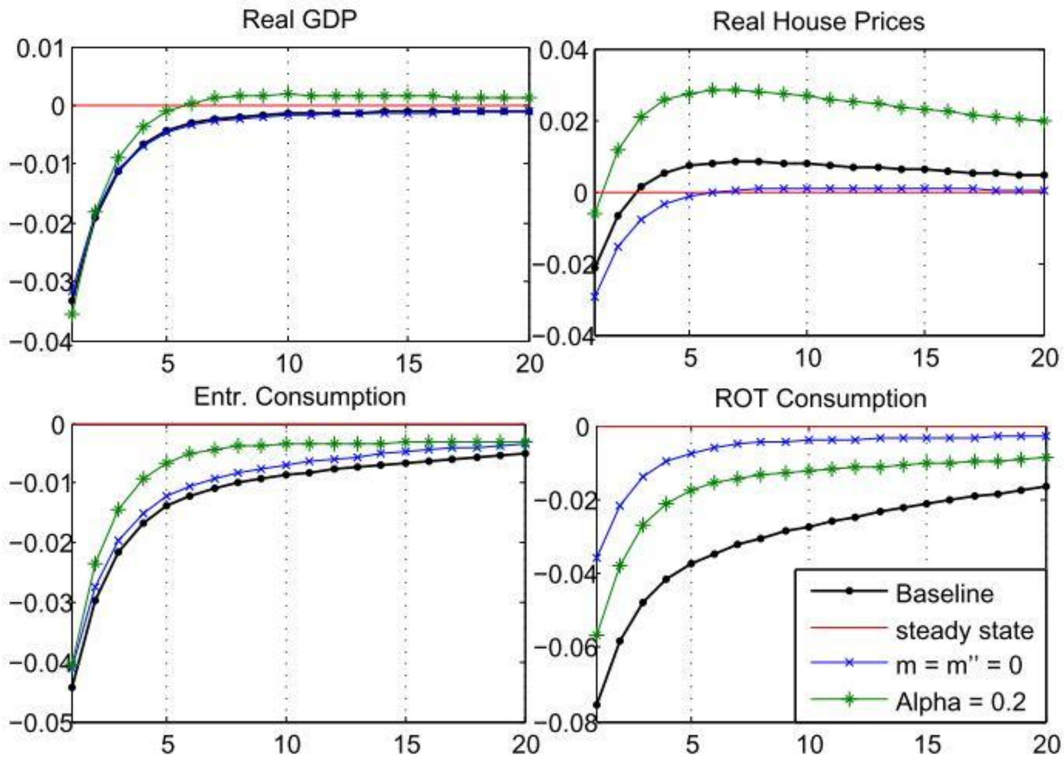


Figure 20 – Impulse responses for different scenarios. Separated the effect of a small monetary policy shock in the baseline scenario (Black curve), reduced constrained household wage share (Green curve) and no-collateral effects (Blue curve).

I obtained similar results as Aoki et al. (2001) in their Bank of England Quarterly Bulletin. Note, however, that they consider instead a reduction in the wage share of ROT consumers. An unanticipated monetary tightening leads to an initial reduction in house prices. This worsens the financial position of the borrowers through increased LTV ratio and therefore reduces their consumption as well. Since impatient households react more strongly to changes in their current income, increased wage share of ROT consumers will therefore lead to an increased effect on aggregate demand, as shown in the real GDP graph. Aggregate effect on consumption is not shown as consumption in this model is separated into three different segments; entrepreneurial consumption, PIH type consumption and ROT consumption. As we see from figure 20, the effect of increased ROT consumers leads to a much larger initial effect on real house prices, and therefore a larger effect on inflation as well (not shown in the graph). Clearly, the wage share of the consumers also displays an amplification mechanism that leads to increased consumption for constrained agents when compared to the case of no collateral effect. Comparing reduced alpha to the baseline case (black curve) we see that the effect on ROT consumption is smaller. This may be due to the dual identity of alpha; proxies for number of ROT consumers as well as the case of restricting the ease of credit unrelated to housing. In the recent years we have, nonetheless, seen quite a different trend. While I look at what happens when the number of ROT consumers increase, the developments in Norway are rather conflicting. First, average maturing time for mortgage debt has increased from 15 to 23 years during the last decade. Second, the size of the mortgage does not matter as much anymore; instead a more common practice for banks is to look at the capability of agents in servicing and taking on new debt. The increased popularity of the no-annuity period in has also contributed on this matter. Opposing these effects are the stricter guidelines from the Financial Supervisory Authority for Norway, requiring additional collateral for loans with exceeding 90% LTV ratio.

Also note that the correlation between ROT consumers' consumption and real house prices turns negative and near zero after lowering α from 0.73 to 0.2 (Appendix C). A negative, although small, correlation implies that as one variable goes up the other goes down. Perhaps counter intuitively, this says that an increase in the house prices from steady state is accompanied by reduced consumption for ROT consumers when the fraction of ROT consumers increases.

5.5 Central bank reacting to house prices

I now turn my attention to the central bank and their role. In this section I intend to add house prices to the reaction function of the central banks to see if and how monetary policy is affected by this. I check weather introducing a central bank reaction towards asset price stabilisation leads to higher volatility in output and inflation in this model. The central bank will now focus on large variations in asset prices (residential and non-residential prices in this model), last period's inflation, output deviations and interest rate smoothing. The following interest rate rule is implemented in the Dynare4.2.0 estimation procedure:

$$Rhat_t = r_R Rhat_{t-1} + (1 - r_R)\big(r_q qhat_t + (1 + r_\pi)\pi hat_{t-1} + \ r_Y Yhat_{t-1}\big) + ehat_{R,t}$$

Note, nonetheless, that I will use the same priors for both types of monetary policy choice functions. In doing so I follow the lead of Bache et al. (2010) in their study: "*This is meant to reflect the heroic assumption that these parameters are truly structural*."

There is a large literature of researchers including asset prices in their respective policy specification. A thorough insight into the literature will go beyond the scope of this thesis, I will, however, briefly go through some main results. As noted above, Iacoviello (2005) finds that there are gains in targeting asset prices in terms of output and inflation stabilisation. He argues for a positive weight on asset price deviations, r_q, around 0.1-0.15, although his results are not statistically significant. Mendicino and Pescatori (2005) also arrive to the same conclusion in their stylised DSGE model. Svenson (2004) reasons in a similar manner as the authors above, claiming (in a briefing paper for the ECB governor) that central banks should not include asset prices in their policy rule in normal times. In normal times it is up to the supervisory authorities to monitor the market for indicators of financial instability and report well ahead with appropriate regulatory and supervisory action. This is a benefit as a whole because it only applies in times of crisis or great instability. Financial stability becomes then a constraint only when expansionary monetary policy is required, affecting monetary policy only in gloomy times. He goes on to discuss the limited amount of information the central bank has prior to excessive asset price surges and the hardship in identifying the consequences of bubbles bursting. Pre-emptive action to moderate asset price movements, therefore, will not be usable in practice, ibid.: "*Furthermore, whereas the principles for good monetary policy are simple, the practice of good monetary policy is difficult.*"

Faia and Monacelli (2007) instead find (perhaps counter intuitively) that the monetary authorities should respond to increased asset prices by lowering the interest rate. The intuition behind their finding is that the asset price is analogous to a tax that distorts the dynamic evolution for investment. A central bank with a stark distaste for inflation will, though, not experience any welfare gains in targeting asset prices. Only those with a specific Taylor type rule with coefficient on inflation ranging between 1 and 2 experience a gain in welfare. This is however not different from what is found in central banks around the world, as well as Norway. This is illustrated in their 3D graph, figure 21, depicting welfare, inflation and asset prices. When the coefficient of inflation deviation is low, then there are gains in reacting to asset prices.

Estimating the model with the asset prices, I found, led several of the other parameters t-statistics to decrease in magnitude. r_q obtained a low t-value (0.21), implying statistical insignificance just like Iacoviello (2005) in his US study. Most of the posteriors remained around their prior means, while the standard deviation of the shocks did in fact increase slightly in magnitude. The policy coefficients were estimated to 0.91, 0.67, 1.38 and 0.03 for $r_R,\ r_Y,\ r_\pi\ and\ r_q$, respectively. These indicate that interest rate smoothing is actively sought out for the monetary policy authorities, although less importance is assigned to output deviations interest smoothing than for. A great deal of importance is also assigned to inflation stabilisation, which is to be expected as the central bank is still considered following a flexible inflation targeting regime. A flexible inflation targeting regime implies that the central bank aims to keep inflation low and stable, yet still assigning weight to output deviations. It is assumed to partly accommodate inflationary pressures in the short run in order to avoid excessive instability of output and unemployment.

I illustrate the impulse responses to three cases of monetary policy specification. One where r_q is set to zero, one where r_q is set to the estimated value of 0.0348 and one in which I use the one Iacoviello (2005) suggests in his study, namely 0.15.

We see from the impulse response functions that a monetary tightening leads to no significant effect on the impulse responses. The impulse responses of the cost-push shock and the technology shock are given in appendix C, as they reveal the same pattern. The situation is slightly different when considering a shock to technology, however. These impulse responses are illustrated in figure 22 and 23, respectively.

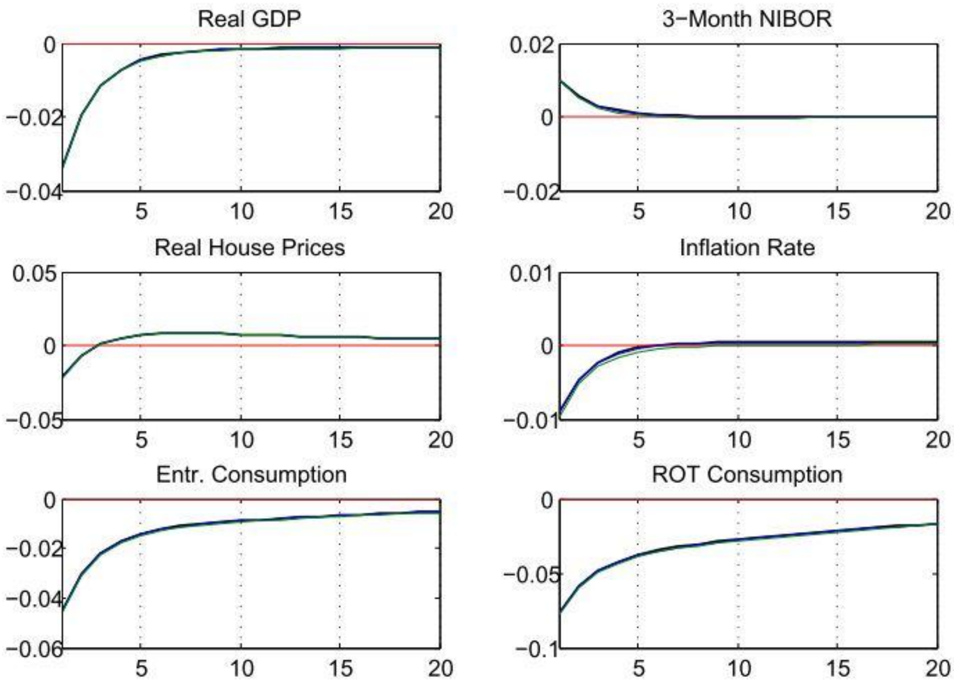


Figure 22 – Impulse responses to a negative monetary policy shock. Black curve depicts the case when rq=0, blue curve when rq=0.03 (estimated value) and green curve when rq=0.15 (as implied by Iacoviello (2005)).

Reacting to asset prices, here residential and non-residential prices, leads to greater effect on output, consumption and inflation. My simulation results reveal that the variance of aggregate output does decrease slightly from reacting to asset prices, but the variance of the inflation rate is instead increased marginally as well. If these changes are statistically different remains unknown in this thesis.

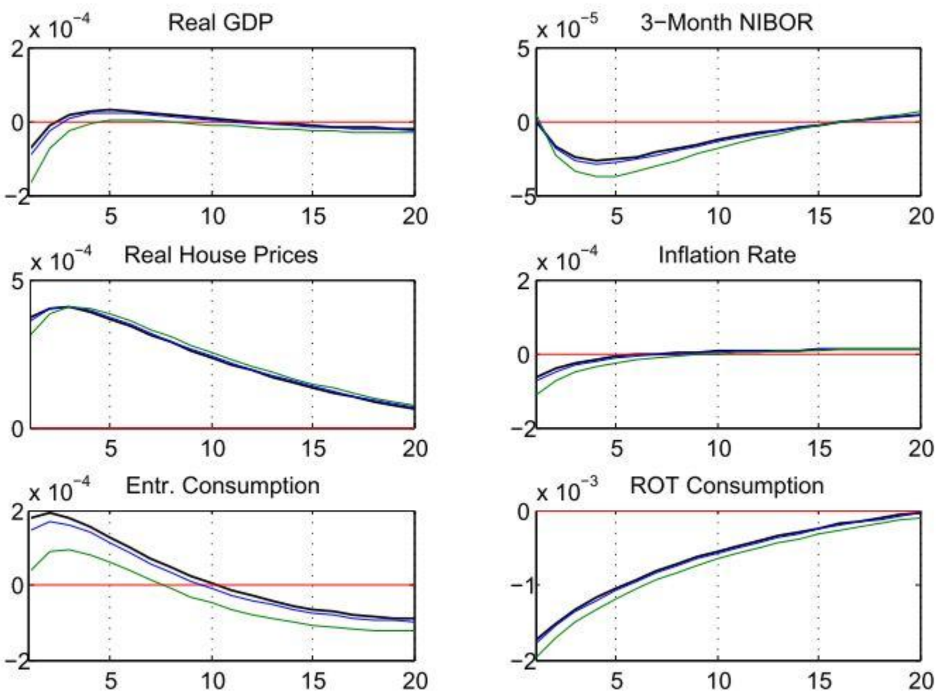


Figure 23 – Impulse responses to a positive technology shock. Black curve depicts the case when rq=0, blue curve when rq=0.04 (estimated value) and green curve when rq=0.15 (implied by Iacoviello (2005)).

This was a rather simplistic way of analysing the effects of incorporating asset prices into the policy function. I arrive to the similar result as Iacoviello (2005), in that introducing asset prices into the policy specification is statistically insignificant at the 1%, 5% as well as the 10% significance level.

6 Limitations and Areas of Further Research

I started off with a plan of incorporating an open economy model for Norway, of which is an economy that is heavily affected by the developments from the rest of the world. The financial market is starkly interlinked with the rest of the world as well. The size of the oil sector in Norway will also be of great importance. And we will have an interlinkage between the oil producing sector and companies that deliver goods and services to the sector. This means that Norway will be heavily exposed to oil price shocks that adversely affect our trading partners. The decrease of the oil price to $20-30 per barrel, among other notable events, during the financial crisis led to declining stock markets. The Norwegian stock market is very reliant on the oil producing sector and a large portion of stocks on the OBX are directly affected by the oil price. In the fall of 2007 until Feb. 2009 the stocks on OBX experienced a reduction in value of more than 50%. Due to the complexity of finding a relevant and simple enough model I could work with, I ended up using a closed economy model instead, developed by Matteo Iacoviello for the US economy. Another possible extension to the model may be including a housing construction sector in the model as Neri and Iacoviello (2010) do in their model. They also add land as another input into the production function for new homes. Something that could be of importance since it ads another financial accelerator effect in the supply side, in addition to the collateral effects on the demand side.

I also implemented asset prices into the monetary policy specification in a simplistic manner. This was never the main part of this thesis; it is rather meant as an addition to the analysis of the financial accelerator and was rather intended as the discussion part of the thesis. In the literature on the subject, there are many ways of measuring the effects. Iacoviello (2005) uses inflation-output volatility frontiers to measure these effects. Mendicino and Pescatori (2005), as well as Faia and Monacelli (2007), measure these effects through a welfare function consisting of goods consumption of the households.

I have not done any extensive sensitivity analysis of my estimates and data, although I had my mind set on doing this from the beginning. Shutting off the shocks and rigidities one at the time could have provided me with better insight into how robust my estimates really are. Another possible way of doing this is to estimate my model using different data on house prices or GDP, use the GDP deflator instead of CPI-ATE, or even use a larger and/or different dataset than was used in my model. I looked into the option of using data from further back than 1995, and perhaps incorporate more cycles into the model estimation. This option was sadly not pursued further due to time limitations. Due to the small sample period in my data, I was also sceptic regarding a division of my data into subsamples and see how this may affect my estimates. The closest I got to a sensitivity analysis was re-estimating the model using the posterior estimates from the Bache et al. (2010) paper for the monetary policy function and inserting a policy specification incorporating residential and non-residential prices.

Including more shocks to the economy has proven its worth in replicating the real world in a more precise manner than a model consisting of just a few shocks. A more complex and realistic model incorporating more shocks is perhaps better at replicating the business cycles in the data. It goes without saying that more shocks lead to more explanatory power, but it also leads to problems regarding which shocks account for what. This is also a possible area of improvement for future analysis. Incorporating more shocks, though, requires more observable variables if one wants to avoid the problem of stochastic singularity, something I did not pursue further either. Smets and Wouters (2007) use seven types of structural shocks, as well as several types of nominal rigidities. Other models, Neri and Iacoviello (2010), also incorporate wage rigidities for instance, as well as 6 types of structural shocks.

7 Conclusion

“Science is facts; just as houses are made of stones, so is science made of facts; but a pile of stones is not a house and a collection of facts is not necessarily science.”

Henri Poincare, French mathematician and physicist

The financial accelerator effect is a recently discovered phenomenon and, as noted in the introduction, there are several different channels the financial accelerator amplification mechanism works through. I have chosen to focus on the financial accelerator mechanism within the housing market. Having used a DSGE framework and incorporated heterogeneous consumers in a model with financial frictions, I measured the importance of the collateral effects via the entrepreneurial sector along with constrained consumers. I then estimated the model using a Bayesian approach, calibrated the relevant parameters and estimated the rest. The estimation procedure yielded results similar to other research on the area of financial accelerators. It is a remarkable fact that there has not been much research going extensively into the financial accelerator effect within the Norwegian housing market. This paper is meant to shine a light on this area of research and perhaps contribute with some new insights into the spillovers from the housing market to the general economy.

I found that the collateral effects are very important in amplifying and propagating the effects of monetary shocks to the economy. Absent the collateral effects, an increase in the demand for housing would produce an increase in housing prices and a reduction in consumption. The collateral effects are able to amplify the initial shock through the change in the LTV ratio and the capability of borrowers to obtain more financing. This is something the traditional wealth effect is not able to explain. The traditional wealth effect postulates that developments in the housing market do not yield any aggregate wealth effect per se. The reason behind this assumption is because developments in the housing market are just considered as a re-distribution away from a first-time borrower to the last-time seller, and not an increase in aggregate. This is especially the case since houses are not built to be exported. Through the impulse response functions I have shown that consumers displaying ROT type behaviour, facing collateral constraints, increase their consumption via Home-Equity-Loans following an increase house prices after an iid. monetary policy shock. I also found that a technology shock instead decelerates the fluctuations in the economy, shown by the impulse responses on consumption. Regulations aimed at restricting the ease of credit for households will, ceteris paribus, have greater impact in aggregate demand as well as real house prices, as shown through a monetary tightening. The effect on consumption for ROT type consumers is greater than the no-collateral scenario, yet below baseline case with LTV ratios of 80% for impatient households and 35% for entrepreneurs. In other words, collateral effects and a high wage share of unconstrained households lead to the greatest effect on consumption. Lastly, I implemented asset prices in the policy specification of the central bank and found that the coefficient assigned to asset prices is not statistically significant at the 1%, 5% or even 10% level. This is similar to Iacoviello (2005) study I followed heartily.

References

Books

D. N. DeJong and C. Dave, *Structural Macroeconometrics*, The University Press Group Ltd, 2007

J. Gali, *Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework*, 2008. Princeton University Press.

J. A. Rice, *Mathematical Statistics and Data Analysis*, third edition 2007, Thomson – Brooks/Cole

C. E. Walsh, *Monetary Theory and Policy*, 2003 third ed. 2010, The MIT Press.

Papers

Ahearne A. G., Ammer J., Doyle B.M., Kole L.S. and Martin R. F., *House Prices and monetary policy: A cross country study*, International Finance Discuccion papers, Number 841, Sept. 2005

An S. and Schorfheide F., Bayesian Analysis of DSGE Models, Econometric Reviews, 26(2–4):113–172, 2007

Angelini P., Neri S. and Panetta F., *Monetary and Macroprudential Policies*, Banca d'Italia - Economic Outlook and Monetary Policy Department, September 2010.

Aoki K., Proudman J. and Vlieghe G., *House Prices, consumption, and monetary policy: a financial accelerator approach*, Journal of Financial Intermediation 13 (2004) 414-435

Aoki K., Proudman J. and Vlieghe G., *Why house prices matter*, Bank of England Quarterly Bulletin, Winter 2001

Bache I. W., Jore A. S., Mitchell J. and Vahey S.P., *Combining VAR and DSGE forecast densities by 2009*, Working Paper at Norges Bank No. 23/2009

Bache I. W., Brubakk L. and Maih J., *Simple rules versus optimal policy: what fits?*, Working Paper at Norges Bank No. 03/2010

Bernanke B., The Financial Accelerator and the Credit Channel, Speech at The Credit Channel of Monetary Policy in the Twenty First Century Conference, Federal Reserve bank of Atlanta, Atlanta, Georgia, June 15, 2007. http://www.federalreserve.gov/newsevents/speech/bernanke20070615a.htm

Bernanke B., Gertler M. and Gilchrist S., Chapter 21 - *The Financial Accelerator in a Quantitative Business Cycle Framework*, Handbook of Macroeconomics, Volume 1

Bernanke B., Gertler M. and Gilchrist S., *The Financial Accelerator and the Flight to Quality*, The Review of Economics and Statistics, Vol. 78, No. 1 (feb., 1996), pp. 1-15

Borio C. and McGuire P., *Twin peaks in equity and housing prices?*, BIS Quarterly Review, March 2004

Campbell J. Y. and Cocco J.F., *How do house prices affect consumption? Evidence from micro data*, Journal of Monetary Economics 54 (2007) pp. 591-621

Christensen I. and Dib A., *The financial accelerator in an estimated New Keynesian model*, Review of Economic Dynamics 11 (2008) pp. 155-178

Clarida R., Galì J. and Gertler M., *The Science of Monetary Policy: A new Keynesian Perspective*, Journal of Economic Literature, Vol. 37, No. 4 (Dec., 1999), pp. 1661-1707

Faia E. and Monacelli T., *Optimal interest rate rules, asset prices, and credit frictions*, Journal of Economic Dynamics & Control 31 (2007) pp. 3228–3254

Finanstilsynet, Finansielt utsyn 2011, downloaded 14.04.2011 at 15.00. http://www.finanstilsynet.no/Global/Venstremeny/Rapport/2011/Finansielt_utsyn_2011.pdf

Galì J., Lòpez-Salido J. D. and Vallès J., *Rule-of-Thumb Consumers and the Design of Interest Rate Rules*, Journal of Money, Credit, and Banking, Vol. 36, No. 4 (August 2004)

Gelain P., *The external finance premium in the euro area: A useful indicator for monetary policy*, Working Paper at European Central bank – No. 1171 / April2010

Gerali A., Neri S., Sessa L. and Signoretti F.M., *Credit and banking in a DSGE model of the euro area*, Temi di Discussione (Working Papers) No. 740

Iacoviello M., *House Prices, Borrowing Constraints, and Monetary Policy in the Business Cycle*, The American economic Review, Vol. 95, No. 3 (Jun., 2005), pp. 739-764

Iacoviello M. and Neri S., *Housing Market Spillovers: Evidence from an Estimated DSGE Model*, American Economic Journal: Macroeconomics, Vol. 2, No. 2 (Apr., 2010) pp. 125-164

Kannan P., Rabanal P. and Scott A.M., *Monetary and Macroprudential Policy Rules in a Model with House Price Booms*, IMF Working Paper No. 09/251

Karagedikli Ö., Matheson T., Smith C. and Vahey S., *RBCs and DSGEs: The computational approach to business cycle theory and evidence*, Working Paper Norges bank 17/2008

Kiyotaki N. and Moore J., *Credit Cycles*, The Journal of Political Economy, Vol. 105, No. 2 (April 1997), pp. 211-248

Kriwoluzky A., *Matching Theory and Data: Bayesian Vector Autoregression and Dynamic Stochastic General Equilibrium Models*, EUI Working Papers MWP 2009/27

Mendicino C. and Pescatori A., *Credit Frictions, Housing Prices and Optimal Monetary Policy Rules,* Working Paper No. 42/2004 Universita' Roma Tre

Rubio M., *Fixed and Variable-Rate Mortgages, Business Cycles and Monetary Policy*, Banco de Espana Working Paper No. 0903, 2009

Smets F. and Wouters R., *Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach*, The American Economic Review, Vol. 97, No. 3 (Jun., 2007) pp. 586-606

SSB, *Økonomiske analyser 1/2011: 8. Husholdningene*, Økonomisk utsyn http://www.ssb.no/emner/08/05/10/oa/201101/08hushold.pdf

Svenson L., *Asset Prices and ECB Monetary Policy*, briefing paper for the committee on Economic and Monetary Affairs (ECON) of the European Parliament for the quarterly dialogue with the President of the European Central Bank.

Tsatsaronis K. and Zhu H., What drives housing price dynamics: cross country evidence, BIS Quarterly Review, March 2004

Wieland V., Cwik T., Müller G.J, Schmidt S. and Wolters M., *A New Comparative Approach to Macroeconomic Modeling and Policy Analysis*, Working Paper, Goethe University of Frankfurt, August 2009

Woodford M., *Financial Intermediation and Macroeconomic Analysis*, Journal of Economic Perspectives (2010), 24(4), pp. 21-44

Articles and Newspapers

A special report on property: Between a rock and a living space, Economist.com, Mar 3rd 2011

http://www.economist.com/node/18250431?story_id=18250431&fsrc=rss

A special report on property: Bricks and slaughter, Mar 3rd 2011

http://www.economist.com/node/18250385

Appendix

Appendix A Data sources

Seasonally adjusted mainland GDP in fixed prices (in million NOK), i.e. excluding the oil producing sector. Source: SSB, created Fri Apr 08 16:02:00 CEST 2011

Seasonally adjusted consumer price index – adjusted for taxes and energy prices. Source: SSB, created Fri Apr 08 16:05:58 CEST 2011.

Seasonally adjusted Nominal House Price Index (in thousand NOK, per square meter). Source: NEF, NFF, Finn.no and Econ Pöyry, created Fri Apr 08 16:10:23 CEST 2011.

3 Month NIBOR rate, average value from daily notations. Source: Norges Bank

Savings ratios for several OECD countries, Economic Outlook No. 88 – December 2010 – Annual Projections for OECD Countries. www.OECD.org

http://stats.oecd.org/Index.aspx?DataSetCode=EO88_INTERNET

Financial assets and liabilities for Norwegian households per 31 December 2010. www.SSB.no

http://www.ssb.no/english/yearbook/tab/tab-302.html

Estimation was done using **Dynare 4.2.0**, a freeware programming code usable inside Matlab or Octave, downloadable from here: http://www.dynare.org/download

Data was handled using **Matlab R2010b**, http://www.mathworks.com/

Graphs and charts were drawn using **MS Excel, MS Words** and **SmartDraw VP** (can be downloaded from http://www.smartdraw.com/)

Appendix B HP-filter

Hodrick-Prescott Filter is a smoothing technique used to detrend dataseries, ie. it removes short-term fluctuations that are related to business cycles. It therefore is a neat trick to reveal long term trends in the data.

Mathematically it can be expressed as:

$$GDP = Permanent\ trend + Business\ cycle$$

or

$$x_t = \psi_t + \varepsilon_t$$

$$\min_{\{\psi_t\}} \sum_{t=1}^{T} (x_t - \psi_t)^2 + \lambda \sum_{t=2}^{T-1} \left((\psi_{t+1} - \psi_t) - (\psi_t - \psi_{t-1})\right)^2$$

Where the first sum denotes the goodness of fit and the second term denotes the penalty for Roughness. λ denotes the smoothing parameter and is in the literature 1600 when considering quarterly data.

Real GDP and real house prices have been detrended using HP-filter. If **x** is the m x m matrix I wish to detrend, I first take log of **x** and then run it through a Matlab code using the following command: $\boldsymbol{x}hp = \log(x) - \text{hpf}(\log(x), 1600)$ where 1600 is the smoothing number.

The Matlab code can be found here:

http://www.krannert.purdue.edu/faculty/knaknoi/Econ635/matlab_filter.html

Appendix C Estimation and simulation output

ESTIMATION OUPUT

Estimation results, taken from Dynare4.2.0

parameters

	prior mean	post. mean	conf. interval		prior	pstdev
rhou	0.800	0.9769	0.9615	0.9928	beta	0.1000
rhoj	0.800	0.9491	0.9249	0.9776	beta	0.1000
rhoA	0.800	0.7500	0.6887	0.8172	beta	0.1000
alfa	0.650	0.7318	0.6759	0.7988	beta	0.0500
my	0.300	0.3086	0.2753	0.3432	beta	0.0200
theta	0.750	0.7500	0.6647	0.8322	beta	0.0500
X	1.200	1.2096	1.0429	1.3652	gamm	0.1000
rR	0.670	0.9129	0.8906	0.9325	beta	0.1000
rY	0.450	0.6315	0.5100	0.7551	norm	0.1000
rpi	1.500	1.3603	1.2101	1.5038	gamm	0.1000

standard deviation of shocks

	prior mean	post. mean	conf. interval		prior	pstdev
eRhat	0.010	0.0018	0.0016	0.0021	invg	0.0500
euhat	0.010	0.0019	0.0015	0.0023	invg	0.0500
ejhat	0.010	0.5817	0.4333	0.7199	invg	0.0500
eAhat	0.010	0.0457	0.0356	0.0571	invg	0.0500

RESULTS FROM POSTERIOR MAXIMIZATION

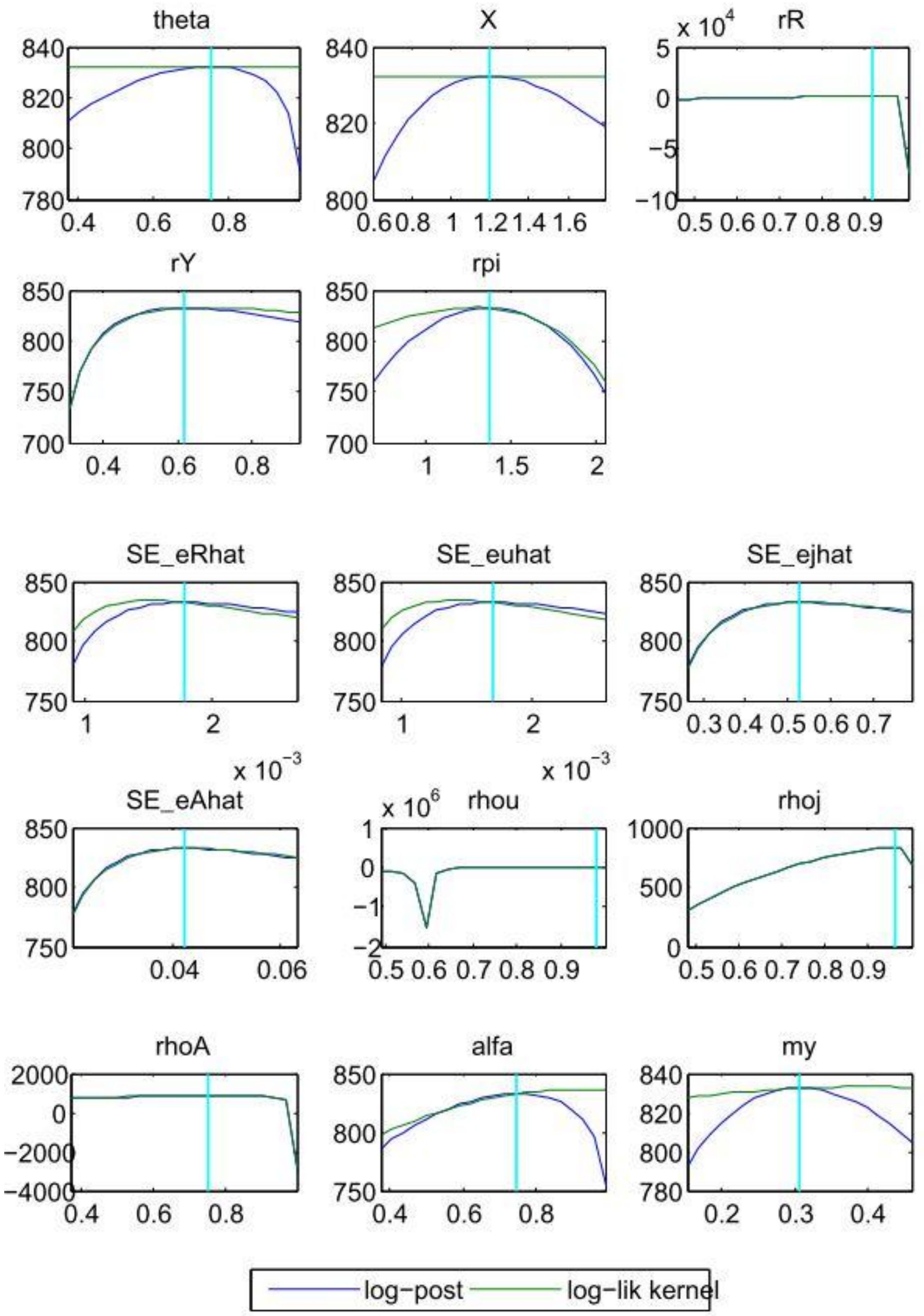
parameters

	prior mean	mode	s.d.	t-stat	prior	pstdev
rhou	0.800	0.9808	0.0097	101.6114	beta	0.1000
rhoj	0.800	0.9603	0.0140	68.5916	beta	0.1000
rhoA	0.800	0.7556	0.0386	19.5883	beta	0.1000
alfa	0.650	0.7486	0.0379	19.7635	beta	0.0500
my	0.300	0.3064	0.0204	15.0480	beta	0.0200
theta	0.750	0.7569	0.0505	14.9745	beta	0.0500
X	1.200	1.1917	0.0997	11.9583	gamm	0.1000
rR	0.670	0.9149	0.0128	71.6820	beta	0.1000
rY	0.450	0.6176	0.0708	8.7236	norm	0.1000
rpi	1.500	1.3637	0.0915	14.9105	gamm	0.1000

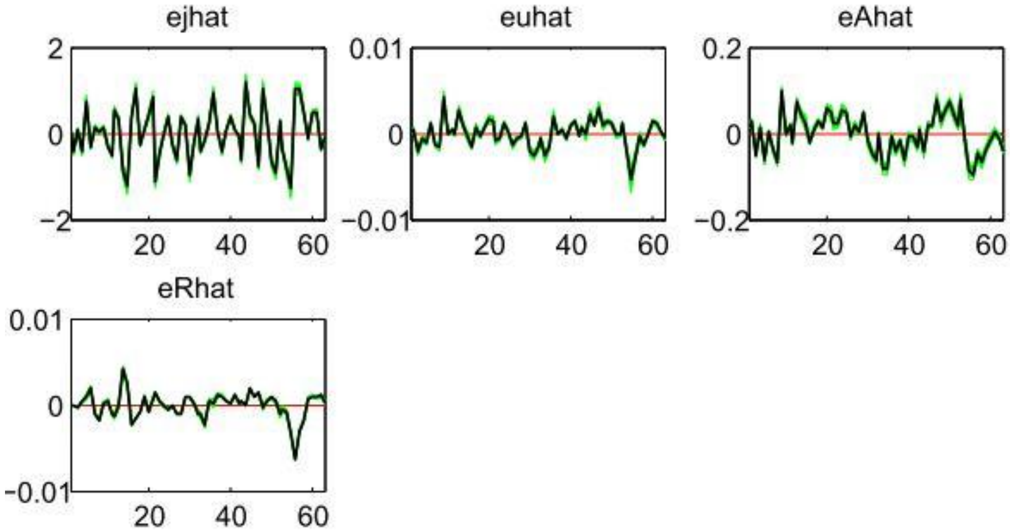
standard deviation of shocks

	prior mean	mode	s.d.	t-stat	prior	pstdev
eRhat	0.010	0.0018	0.0002	11.6197	invg	0.0500
euhat	0.010	0.0017	0.0002	7.7803	invg	0.0500
ejhat	0.010	0.5258	0.0788	6.6691	invg	0.0500
eAhat	0.010	0.0420	0.0057	7.3467	invg	0.0500

Graphs of the the check_plot function in Dynare4.2.0, showing that maximum is truly found The vertical line should coincide with the maximum of the log post (blue) curve, as is the case for all except the AR(1) coefficient for cost-push shock:



Smoothed shocks, these should be around zero. They are indeed around zero.



Estimation results when with alternative policy specification

ESTIMATION RESULTS

Log data density is 781.905283.

parameters

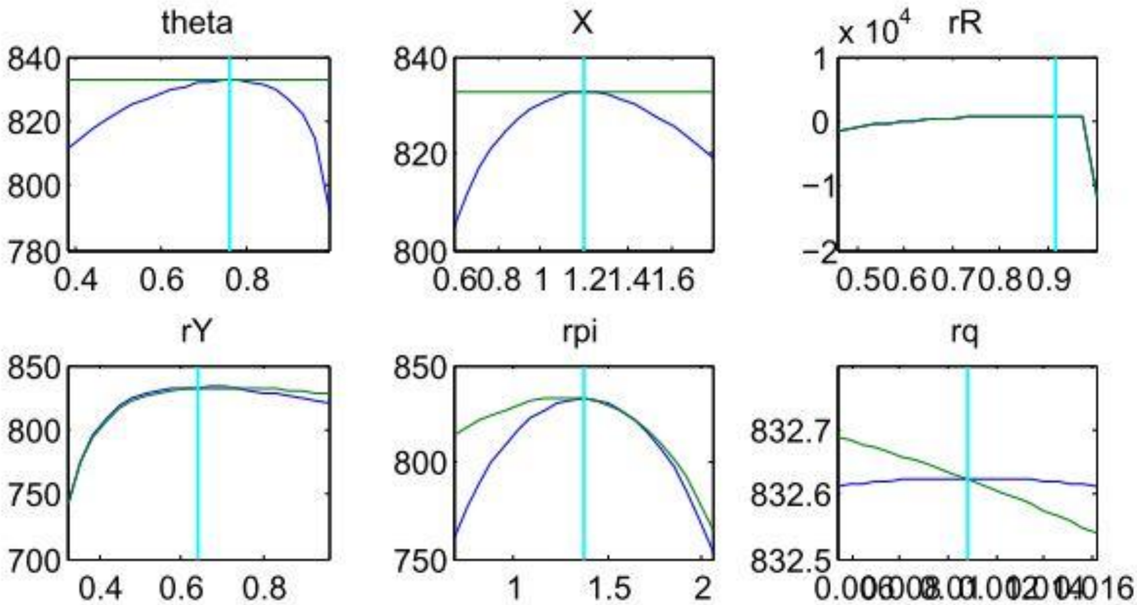
	prior mean	post. mean	conf. interval		prior	pstdev
rhou	0.800	0.9736	0.9567	0.9908	beta	0.1000
rhoj	0.800	0.9568	0.9319	0.9862	beta	0.1000
rhoA	0.800	0.7344	0.6660	0.7934	beta	0.1000
alfa	0.650	0.7408	0.6817	0.7959	beta	0.0500
my	0.300	0.3079	0.2755	0.3411	beta	0.0200
theta	0.750	0.7538	0.6809	0.8262	beta	0.0500
X	1.200	1.1967	1.0551	1.3840	gamm	0.1000
rR	0.670	0.9159	0.8962	0.9376	beta	0.1000
rY	0.450	0.6657	0.5102	0.8077	gamm	0.1000
rpi	1.500	1.3814	1.2345	1.5432	gamm	0.1000
rq	0.150	0.0338	0.0001	0.0691	norm	0.1000

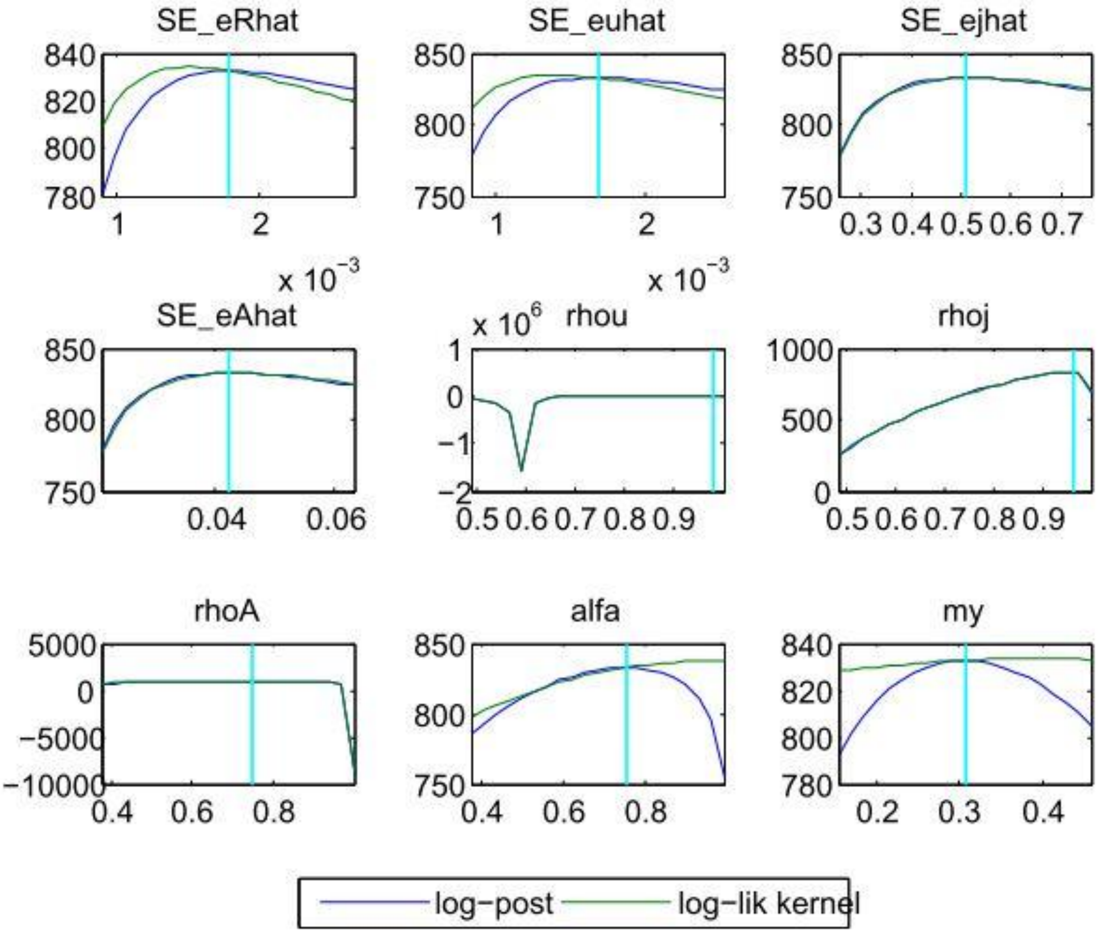
standard deviation of shocks

	prior mean	post. mean	conf. interval		prior	pstdev
eRhat	0.010	0.0018	0.0016	0.0021	invg	0.0500
euhat	0.010	0.0018	0.0014	0.0022	invg	0.0500
ejhat	0.010	0.5354	0.3690	0.6787	invg	0.0500
eAhat	0.010	0.0460	0.0359	0.0557	invg	0.0500

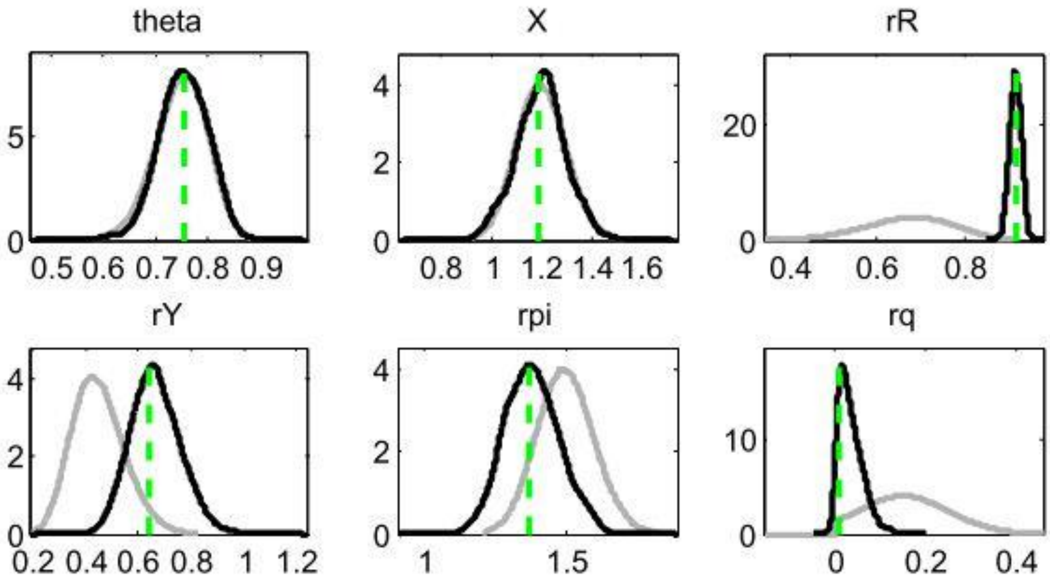
```
RESULTS FROM POSTERIOR MAXIMIZATION
parameters
    prior mean     mode    s.d.  t-stat prior pstdev

rhou     0.800   0.9790  0.0108 90.4894 beta   0.1000
rhoj     0.800   0.9636  0.0191 50.4379 beta   0.1000
rhoA     0.800   0.7494  0.0415 18.0577 beta   0.1000
alfa     0.650   0.7516  0.0384 19.5886 beta   0.0500
my       0.300   0.3061  0.0204 15.0176 beta   0.0200
theta    0.750   0.7569  0.0505 14.9744 beta   0.0500
X        1.200   1.1917  0.0997 11.9583 gamm   0.1000
rR       0.670   0.9157  0.0128 71.5802 beta   0.1000
rY       0.450   0.6394  0.0867  7.3760 gamm   0.1000
rpi      1.500   1.3695  0.0925 14.7991 gamm   0.1000
rq       0.150   0.0108  0.0499  0.2154 norm   0.1000
standard deviation of shocks
    prior mean     mode    s.d.  t-stat prior pstdev

eRhat    0.010   0.0018  0.0002 11.3521 invg   0.0500
euhat    0.010   0.0017  0.0002  7.7788 invg   0.0500
ejhat    0.010   0.5070  0.1146  4.4240 invg   0.0500
eAhat    0.010   0.0423  0.0059  7.1910 invg   0.0500
```

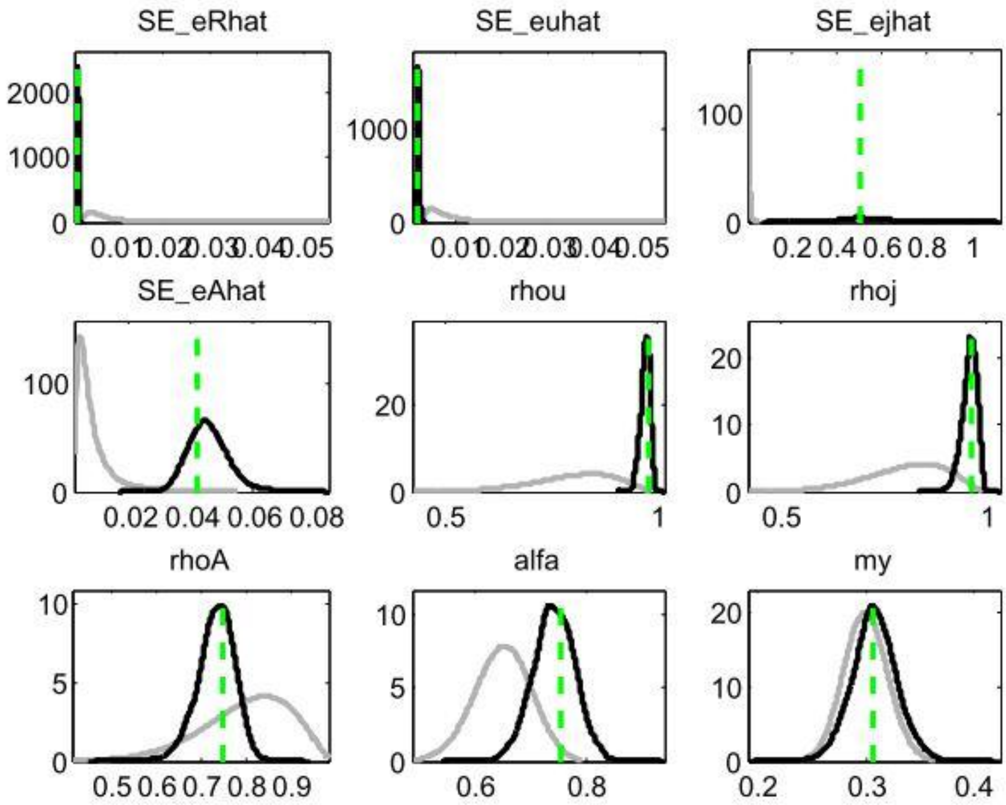
Check-plots:



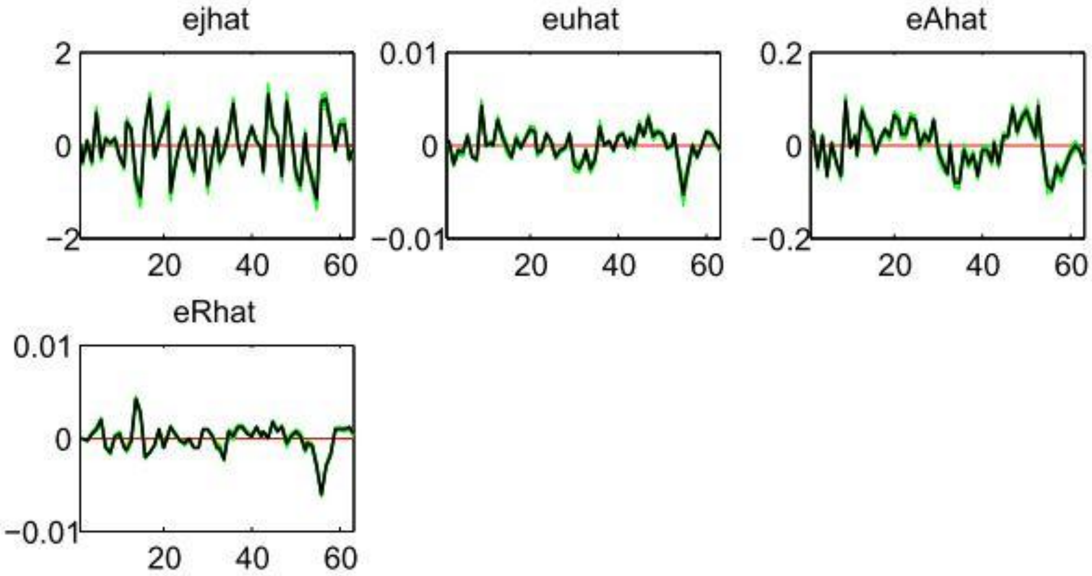


Prior- and posterior distributions:

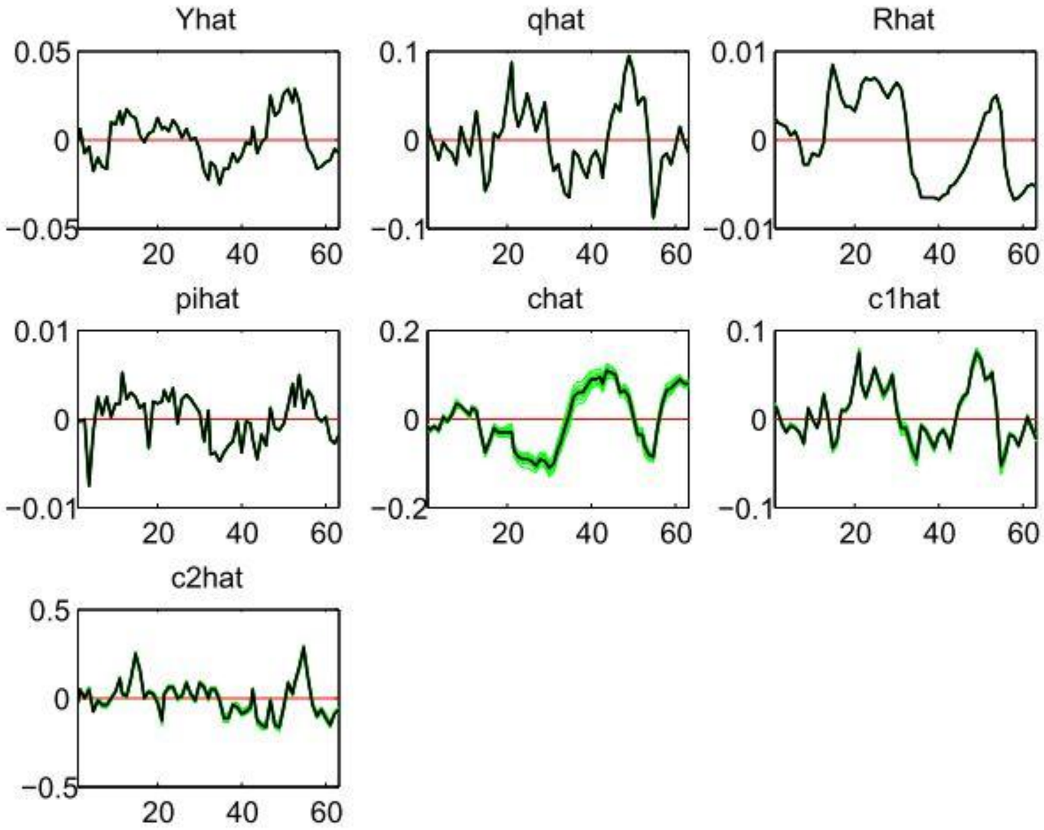




Smoothed Shocks: The shocks are around zero as is expected.



Smoothed variables:



Simulation results, taken from dynare4.2.0

Correlation matrix of the simulated model using m=0.35 and m’’=0.8:

MOMENTS OF SIMULATED VARIABLES

VARIABLE	MEAN	STD. DEV.	VARIANCE	SKEWNESS	KURTOSIS
Yhat	0.144178	0.492809	0.242861	-0.163732	-0.068861
Rhat	-0.063087	0.215342	0.046372	0.147122	-0.086705
qhat	0.096937	0.325746	0.106111	-0.037971	-0.160758
pihat	-0.065257	0.234613	0.055043	0.115937	-0.096426
chat	0.229608	0.934993	0.874212	-0.155750	-0.019446
c2hat	0.174434	0.646591	0.418080	-0.267204	0.118733

CORRELATION OF SIMULATED VARIABLES

VARIABLE	Yhat	Rhat	qhat	pihat	chat	c2hat
Yhat	1.0000	-0.9919	0.9609	-0.8725	0.9791	0.8695
Rhat	-0.9919	1.0000	-0.9661	0.9241	-0.9818	-0.8114
qhat	0.9609	-0.9661	1.0000	-0.8506	0.9180	0.7323
pihat	-0.8725	0.9241	-0.8506	1.0000	-0.8993	-0.6158
chat	0.9791	-0.9818	0.9180	-0.8993	1.0000	0.8259
c2hat	0.8695	-0.8114	0.7323	-0.6158	0.8259	1.0000

Correlation matrix of the simulated model using m=m''=0:

MOMENTS OF SIMULATED VARIABLES

VARIABLE	MEAN	STD. DEV.	VARIANCE	SKEWNESS	KURTOSIS
Yhat	0.145626	0.494162	0.244196	-0.167905	-0.074076
Rhat	-0.062844	0.211610	0.044779	0.158855	-0.087485
qhat	0.081305	0.248525	0.061765	-0.112508	-0.193762
pihat	-0.065552	0.232564	0.054086	0.123737	-0.100229
chat	0.236922	0.969059	0.939075	-0.145231	-0.034075
c2hat	0.232036	0.837256	0.700997	-0.197919	-0.064301

CORRELATION OF SIMULATED VARIABLES

VARIABLE	Yhat	Rhat	qhat	pihat	chat	c2hat
Yhat	1.0000	-0.9943	0.9359	-0.8892	0.9778	0.9926
Rhat	-0.9943	1.0000	-0.9118	0.9307	-0.9809	-0.9923
qhat	0.9359	-0.9118	1.0000	-0.7293	0.8471	0.8885
pihat	-0.8892	0.9307	-0.7293	1.0000	-0.9124	-0.9156
chat	0.9778	-0.9809	0.8471	-0.9124	1.0000	0.9904
c2hat	0.9926	-0.9923	0.8885	-0.9156	0.9904	1.0000

Correlation matrix of the simulated model using α=0.2, m=0.35 and m''=0.8

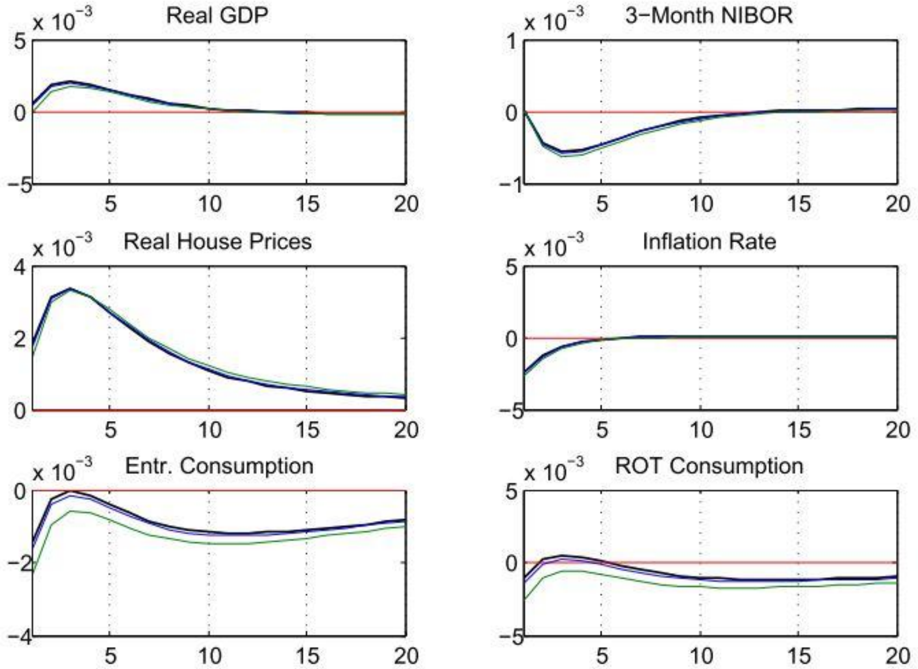
MOMENTS OF SIMULATED VARIABLES

VARIABLE	MEAN	STD. DEV.	VARIANCE	SKEWNESS	KURTOSIS
Yhat	0.118952	0.423018	0.178944	-0.112070	-0.073147
Rhat	-0.052002	0.190875	0.036433	0.069840	-0.089802
qhat	-0.009940	0.349182	0.121928	0.050098	0.092351
pihat	-0.053763	0.208985	0.043675	0.052965	-0.095817
chat	0.201784	0.824235	0.679363	-0.140299	-0.029413
c2hat	0.154398	0.533834	0.284979	-0.271086	0.027060

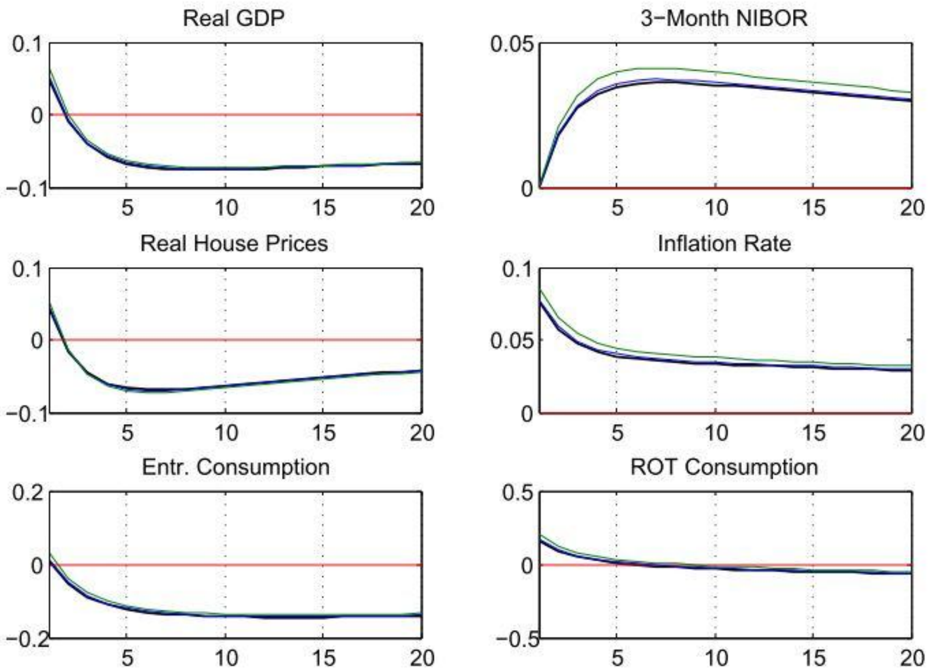
CORRELATION OF SIMULATED VARIABLES

VARIABLE	Yhat	Rhat	qhat	pihat	chat	c2hat
Yhat	1.0000	-0.9817	0.1182	-0.7954	0.9763	0.9061
Rhat	-0.9817	1.0000	-0.2221	0.8833	-0.9839	-0.8233
qhat	0.1182	-0.2221	1.0000	-0.1806	0.0921	-0.2806
pihat	-0.7954	0.8833	-0.1806	1.0000	-0.8683	-0.5988
chat	0.9763	-0.9839	0.0921	-0.8683	1.0000	0.8604
c2hat	0.9061	-0.8233	-0.2806	-0.5988	0.8604	1.0000

Simulation results from estimated model incorporating asset prices in the policy specification.



Impulse responses to a technology shock. Black curve depicts the case when rq=0, blue curve when rq=0.04 (estimated value) and green curve when rq=0.15 (implied by Iacoviello (2005)).



Impulse responses to a cost-push shock. Black curve depicts the case when rq=0, blue curve when rq=0.04 (estimated value) and green curve when rq=0.15 (implied by Iacoviello (2005)).

Simulation when rq=0

MOMENTS OF SIMULATED VARIABLES

VARIABLE	MEAN	STD. DEV.	VARIANCE	SKEWNESS	KURTOSIS
Yhat	0.127152	0.457488	0.209295	-0.141885	-0.037078
Rhat	-0.057292	0.204845	0.041962	0.126487	-0.060122
qhat	0.087909	0.315003	0.099227	-0.023150	-0.132502
pihat	-0.059538	0.226201	0.051167	0.094764	-0.076370
chat	0.201628	0.866498	0.750818	-0.128876	0.007701
c2hat	0.145043	0.577795	0.333847	-0.244039	0.173888

CORRELATION OF SIMULATED VARIABLES

VARIABLE	Yhat	Rhat	qhat	pihat	chat	c2hat
Yhat	1.0000	-0.9894	0.9609	-0.8494	0.9789	0.8295
Rhat	-0.9894	1.0000	-0.9653	0.9139	-0.9809	-0.7551
qhat	0.9609	-0.9653	1.0000	-0.8323	0.9188	0.6806
pihat	-0.8494	0.9139	-0.8323	1.0000	-0.8832	-0.5208
chat	0.9789	-0.9809	0.9188	-0.8832	1.0000	0.7811
c2hat	0.8295	-0.7551	0.6806	-0.5208	0.7811	1.0000

Simulation when rq=0.03

MOMENTS OF SIMULATED VARIABLES

VARIABLE	MEAN	STD. DEV.	VARIANCE	SKEWNESS	KURTOSIS
Yhat	0.126227	0.455189	0.207197	-0.141581	-0.035873
Rhat	-0.058918	0.210097	0.044141	0.124737	-0.063519
qhat	0.087923	0.317586	0.100861	-0.021186	-0.129950
pihat	-0.061243	0.232259	0.053944	0.092952	-0.077928
chat	0.199936	0.859285	0.738370	-0.130140	0.009039
c2hat	0.141626	0.574378	0.329910	-0.234826	0.174261

CORRELATION OF SIMULATED VARIABLES

VARIABLE	Yhat	Rhat	qhat	pihat	chat	c2hat
Yhat	1.0000	-0.9874	0.9599	-0.8430	0.9787	0.8129
Rhat	-0.9874	1.0000	-0.9651	0.9142	-0.9794	-0.7276
qhat	0.9599	-0.9651	1.0000	-0.8297	0.9183	0.6558
pihat	-0.8430	0.9142	-0.8297	1.0000	-0.8782	-0.4860
chat	0.9787	-0.9794	0.9183	-0.8782	1.0000	0.7621
c2hat	0.8129	-0.7276	0.6558	-0.4860	0.7621	1.0000

Simulation when rq=0.15

MOMENTS OF SIMULATED VARIABLES

VARIABLE	MEAN	STD. DEV.	VARIANCE	SKEWNESS	KURTOSIS
Yhat	0.123049	0.447520	0.200275	-0.140178	-0.031645
Rhat	-0.064233	0.227813	0.051899	0.118437	-0.072771
qhat	0.087958	0.326468	0.106581	-0.014768	-0.122085
pihat	-0.066827	0.252785	0.063900	0.086610	-0.082043
chat	0.194127	0.834762	0.696828	-0.134395	0.013878
c2hat	0.129941	0.569068	0.323839	-0.198332	0.169998

CORRELATION OF SIMULATED VARIABLES

VARIABLE	Yhat	Rhat	qhat	pihat	chat	c2hat
Yhat	1.0000	-0.9791	0.9559	-0.8199	0.9778	0.7496
Rhat	-0.9791	1.0000	-0.9637	0.9150	-0.9734	-0.6224
qhat	0.9559	-0.9637	1.0000	-0.8202	0.9160	0.5626
pihat	-0.8199	0.9150	-0.8202	1.0000	-0.8604	-0.3587
chat	0.9778	-0.9734	0.9160	-0.8604	1.0000	0.6911
c2hat	0.7496	-0.6224	0.5626	-0.3587	0.6911	1.0000

Dynare4.2.0 Model Code obtained through the macro model database

```
// Model: US_IAC05

// Further references:
// Matteo Iacoviello. 2005. "House Prices, Borrowing Constraints, and
Monetary Policy in the Business Cycle"
// the American Economic Review 95, pp. 739-764.


//% basic endogenous variable
var Yhat chat c1hat c2hat Ihat Khat Xhat qhat bhat b2hat hhat h2hat Rhat
pihat rrhat

//% Endogenous variables with exogenous dynamics
jhat Ahat uhat;


//% Declaration of exogenous variables (shocks)
varexo
ejhat,
euhat,
eAhat,
eRhat;

parameters

//% deep parameters
beta,
beta2,
gamma,
j,
eta,
my,
ypsilon,
psi,
delta,
fie,
fih,
X,
theta,
alfa,
m,
m2,
rhou,
rhoj,
rhoA,
rR,
rpi,
rY,
gammae,
gammah,
omega,
kappa,
s1,
s2,
qhtoY,
btoY,
c1toY,
qh1toY,
qh2toY,
htoh1,
h2toh1,
b2toY,
c2toY,
ctoY,
ItoY,
jota,
jota2,
h1ss,
sigmau,
sigmaj,
sigmaA,
sigmaR,
R;


//% Setting of numerical values for parameters
```

```
beta = 0.9994;
beta2 = 0.97;
gamma = 0.97;
j = 0.2;
eta = 1.01;
my = 0.3;
ypsilon = 0.03;
psi = 2;
delta = 0.0180;
fie = 0;
fih = 0;
X = 1.20;
theta = 0.75;
alfa = 0.65;
m = 0.35;
m2 = 0.8;
rhou = 0.8;
rhoj = 0.8;
rhoA = 0.8;
rR = 0.8;
rpi = 2;
rY = 0.2;
//sigmau = 0.01;
//sigmaj = 0.01;
//sigmaA = 0.01;
//sigmaR = 0.01;


//% Defined parameters
gammae = (1-m)*gamma + m*beta;
gammah = beta2+m2*(beta-beta2);
omega = (beta2-m2*beta2)/(1-m2*beta);
kappa = (1-theta)*(1-beta*theta)/theta;
s1 = (alfa*(1-my-ypsilon)+X-1)/X;
s2 = (1-alfa)*(1-my-ypsilon)/X;
qhtoY = gamma*ypsilon/(X*(1-gammae));
btoY = beta*m*qhtoY;


qh1toY = j*s1/(1-beta)+j*m*qhtoY+j*m2*s2/(1-beta2-m2*(beta-beta2-j*(1-
beta)));
qh2toY = j*s2/(1-beta2-m2*(beta-beta2-j*(1-beta)));

c1toY = s1+(1-beta)*(m*qhtoY+m2*qh2toY);

htoh1 = qhtoY/qh1toY;
h2toh1 = qh2toY/qh1toY;

b2toY = j*beta*m2/(1-beta2-m2*(beta-beta2)+j*m2*(1-beta))*s2;

c2toY = s2*(1-beta2-m2*(beta-beta2))/(1-beta2-m2*(beta-beta2)+j*m2*(1-
beta));

ctoY = (my+ypsilon-delta*gamma*my/(1-gamma*(1-delta))-(1-
beta)*m*X*qhtoY)/X;
ItoY = 1-ctoY-c1toY-c2toY;
jota = (1-beta)*htoh1;
jota2 = (1-beta)*h2toh1;
R = 1/beta;


model(linear);

Yhat = ctoY*chat+c1toY*c1hat+c2toY*c2hat+ItoY*Ihat;

c1hat = c1hat(+1)-rrhat;

Ihat = Khat(-1)+gamma*(Ihat(+1)-Khat)+(1-gamma*(1-delta))*(Yhat(+1)-
Xhat(+1)-Khat)/(psi)
     +(chat-chat(+1))/(psi);
```

```
qhat = gammae*qhat(+1)+(1-gammae)*(Yhat(+1)-Xhat(+1)-hhat)-m*beta*rrhat
     -(1-m*beta)*(chat(+1)-chat)-fie*(hhat-hhat(-1)-gamma*(hhat(+1)-hhat));

qhat = gammah*qhat(+1)+(1-gammah)*(jhat-h2hat)-m2*beta*rrhat+(1-
m2*beta)*(c2hat-omega*c2hat(+1))
     -fih*(h2hat-h2hat(-1)-beta2*(h2hat(+1)-h2hat));

qhat = beta*qhat(+1)+(1-beta)*jhat+jota*hhat+jota2*h2hat+c1hat-
beta*c1hat(+1)
     +fih*(htoh1*(hhat-hhat(-1))+h2toh1*(h2hat-h2hat(-1))-
beta*htoh1*(hhat(+1)-hhat)-beta*h2toh1*(h2hat(+1)-h2hat));

bhat = qhat(+1)+hhat-rrhat;

b2hat = qhat(+1)+h2hat-rrhat;

Yhat = eta*(Ahat+ypsilon*hhat(-1)+my*Khat(-1))/(eta-(1-ypsilon-my))
     -(1-ypsilon-my)*(Xhat+alfa*c1hat+(1-alfa)*c2hat)/(eta-(1-ypsilon-my));

pihat = beta*pihat(+1)-kappa*Xhat+uhat;

Khat = delta*Ihat+(1-delta)*Khat(-1);

btoY*bhat = ctoY*chat+qhtoY*(hhat-hhat(-1))+ItoY*Ihat+R*btoY*(Rhat(-
1)+bhat(-1)-pihat)
          -(1-s1-s2)*(Yhat-Xhat);

b2toY*b2hat = c2toY*c2hat+qh2toY*(h2hat-h2hat(-1))+R*b2toY*(b2hat(-
1)+Rhat(-1)-pihat)-s2*(Yhat-Xhat);

Rhat = (1-rR)*(1+rpi)*pihat(-1)+rY*(1-rR)*Yhat(-1)+rR*Rhat(-1)+eRhat;


//**********************************************************************
//Alternative policy specification

//Rhat = rR*Rhat(-1)+(1-rR)*(rq*qhat+(1+rpi)*pihat(-1)+rY*Yhat(-1))+eRhat;

//**********************************************************************

//% Defined variable(s)
rrhat = Rhat-pihat(+1);

//% equations for variables with exogenous AR(1)-dynamics
jhat = rhoj*jhat(-1)+ejhat;
uhat = rhou*uhat(-1)+euhat;
Ahat = rhoA*Ahat(-1)+eAhat;

end;

//**********************************************************************
         //Needed to simulate the model
            //shocks;
            //var eRhat;
            //stderr sigmaR;
            //var euhat;
            //stderr sigmau;
```

```
            //var ejhat;
            //stderr sigmaj;
            //var eAhat;
            //stderr sigmaA;
            //end;


            //stoch_simul(periods=5000,simul_seed=1, irf=20) Yhat Rhat qhat
pihat chat c2hat;

//**************************************************************************

estimated_params;

stderr eRhat, inv_gamma_pdf,0.01,0.05;
stderr euhat, inv_gamma_pdf,0.01,0.05;
stderr ejhat, inv_gamma_pdf,0.01,0.05;
stderr eAhat, inv_gamma_pdf,0.01,0.05;
rhou, beta_pdf, 0.8, .1;
rhoj, beta_pdf, 0.8, .1;
rhoA, beta_pdf, 0.8, .1;
alfa, beta_pdf, 0.65, 0.05;
my, beta_pdf, 0.3, .02;
theta, beta_pdf, 0.75, 0.05;
rR, beta_pdf, 0.8, 0.1;
//rY, normal_pdf, 0.2, 0.15;
rpi, gamma_pdf, 2, 0.1;


end;


estimated_params_bounds;
stderr eRhat, 0.0001, 100;
stderr euhat, 0.0001, 100;
stderr ejhat, 0.0001, 100;
stderr eAhat, 0.0001, 100;
rhou, .001,.9999;
rhoj, .001,.9999;
rhoA, .0001,.9999;
alfa, 0,.99;
my, 0,.99;
theta, 0,.99;
rR, 0,.9999;
//rY, 0,10;
rpi,0,10;

end;


estimated_params_init;
stderr eRhat, 0.01;
stderr euhat, 0.01;
stderr ejhat, 0.01;
stderr eAhat, 0.01;
rhou, 0.8;
rhoj, 0.8;
rhoA, 0.8;
```

```
alfa, 0.65;
my, 0.3;
theta, 0.75;
rR, 0.9;
//rY, 0.2;
rpi, 2;
end;


varobs Yhat pihat qhat Rhat;

// bayesestimation

estimation(datafile=”filename”,conf_sig
=.95,smoother,mode_check,mode_compute=1,mh_replic=2000,mh_jscale=0.55,mh_nb
locks=1,prior_trunc=0) Yhat Rhat pihat qhat chat c1hat c2hat;
```

Appendix D Data manipulation

- Real GDP was log transformed and HP-filtered via Matlab R2010b
- Real house prices were found by using the following formula:

Real Houseprices = Nominal Houseprices/Price Index

- Real house prices were then log transformed and HP-filtered
- 3-Month annualised NIBOR was given in monthly values, from daily notations. Quarter average was found and demeaned by deducting the average of the time series from 1995-2010. Was then multiplied by 3 and divided by 12 in order to de-annualise them. Was also divided by 100 in order to be directly compared to the other time-series.
- CPI-ATE was seasonally adjusted and given in monthly values. Quarter average was found and demeaned by deducting the mean of the time series. Divided by 100 in order to be directly compared to GDP and house prices. The inflation rate was found using the following formula:

  Inflation Rate = $(CPI_t - CPI_{t-1})/CPI_{t-1}$

- The first observation is therefore lost using this transformation, yielding me 63 observations instead of 64.

	CPI-ATE		NIBOR		GDP		House price index
01.01.1995	91.30	januar 95	5.76	01.01.1995	257113	1995Q1	40.3
01.02.1995	91.50	februar 95	5.46	01.04.1995	258120	1995Q2	42
01.03.1995	91.70	mars 95	5.39	01.07.1995	262294	1995Q3	42.7
01.04.1995	91.80	april 95	5.36	01.10.1995	260635	1995Q4	43.2
01.05.1995	91.90	mai 95	5.67	01.01.1996	263442	1996Q1	43.7
01.06.1995	92.00	juni 95	5.79	01.04.1996	261907	1996Q2	45.7
01.07.1995	92.10	juli 95	5.62	01.07.1996	266038	1996Q3	46.6
01.08.1995	92.30	august 95	5.34	01.10.1996	266835	1996Q4	47.7
01.09.1995	92.40	september 95	5.36	01.01.1997	268386	1997Q1	48.4
01.10.1995	92.60	oktober 95	5.34	01.04.1997	277845	1997Q2	51.8
01.11.1995	92.60	november 95	5.22	01.07.1997	279446	1997Q3	52.3
01.12.1995	92.80	desember 95	5.43	01.10.1997	283821	1997Q4	52.9
01.01.1996	92.40	januar 96	5.48	01.01.1998	283573	1998Q1	55.2
01.02.1996	92.30	februar 96	5.26	01.04.1998	288195	1998Q2	58.6
01.03.1996	92.40	mars 96	4.92	01.07.1998	288959	1998Q3	58
01.04.1996	92.50	april 96	4.70	01.10.1998	290378	1998Q4	56.5
01.05.1996	92.70	mai 96	4.76	01.01.1999	289421	1999Q1	58.7
01.06.1996	92.70	juni 96	4.93	01.04.1999	290163	1999Q2	63.4
01.07.1996	93.10	juli 96	4.99	01.07.1999	293346	1999Q3	64.7
01.08.1996	93.30	august 96	5.02	01.10.1999	295339	1999Q4	67
01.09.1996	93.40	september 96	5.09	01.01.2000	299104	2000Q1	71
01.10.1996	93.50	oktober 96	5.04	01.04.2000	298979	2000Q2	75.7
01.11.1996	93.70	november 96	4.39	01.07.2000	300975	2000Q3	73.5
01.12.1996	93.90	desember 96	4.14	01.10.2000	301616	2000Q4	73.5

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01.03.1997	94.40	mars 97	3.51
01.04.1997	94.60	april 97	3.50
01.05.1997	94.70	mai 97	3.46
01.06.1997	95.00	juni 97	3.51
01.07.1997	95.10	juli 97	4.00
01.08.1997	95.40	august 97	4.04
01.09.1997	95.50	september 97	3.94
01.10.1997	95.70	oktober 97	3.97
01.11.1997	95.90	november 97	3.95
01.12.1997	96.10	desember 97	3.87
01.01.1998	96.50	januar 98	3.82
01.02.1998	96.80	februar 98	3.84
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01.07.1998	97.90	juli 98	5.35
01.08.1998	98.10	august 98	6.74
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01.10.1998	98.60	oktober 98	7.92
01.11.1998	98.80	november 98	7.96
01.12.1998	99.00	desember 98	8.24
01.01.1999	99.10	januar 99	7.72
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01.07.1999	100.00	juli 99	6.35
01.08.1999	99.90	august 99	6.09
01.09.1999	100.20	september 99	5.97
01.10.1999	100.50	oktober 99	6.37
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2008Q1	0.02060	0.04711	0.003206	0.003869
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2009Q2	-0.00994	-0.02216	-0.00555	0.00244
2009Q3	-0.01735	-0.01718	-0.00697	0.000138
2009Q4	-0.01556	-0.02975	-0.00656	-0.00044
2010Q1	-0.01331	-0.00872	-0.00601	0.0001
2010Q2	-0.01133	0.01479	-0.0054	-0.00243
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